Technical Memorandum

To:	Joanne Daneel	**From:**	Dr Andrea Baker & Vibhishan Moodley
Company:	Trinity Metals	**SLR Consulting (Africa) Proprietary Limited**	
cc:	Sam Ryumugabe	**Date:**	2 December 2025
		Project No.	713.000084.00002

RE: Trinity Metals Legacy Tailings and River Rehabilitation: Geochemical and Soil / Sediment Assessments – Rutongo Mines, Rwanda

1.0 Introduction

Trinity Metals Limited was formed in May 2022 with the amalgamation of the three mines namely, Rutongo, Musha and Nyakabingo under the Trinity Metals Group. All three mines have a long history of artisanal-scale mining which dates to the Belgian times in the late 1930's. This has resulted in significant environmental and social legacy issues, including altering the natural hydrological functioning of the river systems and associated water quality impacts.

Trinity Metals are committed to the expansion, modernisation and mechanisation of its mining operations as well as addressing the current and historical mining-related environmental and social impacts in a responsible and sustainable manner. Consequently, technical assistance (TA) programs have been developed to assist in identifying and assessing existing environmental and social (E&S) impacts to implement management plans and programs that address those E&S impacts identified. As part of TA 4, the development of legacy tailings management and river rehabilitation plans look to include different specialist studies and technical task teams to address the impacts.

Consequently, Trinity Metals has appointed SLR Consulting (Africa) Proprietary Limited (SLR) to undertake:

- A geochemical baseline assessment of the legacy tailings lithologies that are integrated with the Rutongo mines to determine their acid rock drainage and metal leaching potential risk,
- A geochemical baseline assessment of the river sediments to determine their capacity to remediate any metal leaching and acid rock drainage that might be emanating from the legacy tailings lithologies, and
- A baseline assessment of the downstream soils to assess their physical and chemical properties and their capacity to remediate any metal leaching and acid rock drainage risks that might be emanating from the legacy tailings lithologies.

2.0 Scope of Work

The proposed scope of work to achieve the project objectives is detailed below.

1. Desktop study
    a. Gap analysis and request for information.
    b. Sampling schedule plan development using a regular point sampling methodology and expert knowledge to locate sampling points.
2. Site sampling visit to the Rutongo mines to:
    a. Locate QGIS and expert knowledge determined sampling points,
    b. Undertake visual soil assessment to classify the soils based on the IUSS working group reference base,
    c. Collect designated soil and sediment samples for analysis to confirm classification and delineate any contaminants,
    d. Identify, describe and sample representative legacy tailings lithologies for geochemical assessment,
3. Specialist laboratory analysis program
    a. River sediment assessment analysis:
        i. Particle size distribution (PSD) analysis
        ii. X-ray diffraction (XRD) mineralogy
        iii. Synthetic Precipitation Leachate Procedure
        iv. Total metal concentrations
    b. Legacy Tailings assessment analysis:
        i. XRD minerology
        ii. Acid base accounting and sulfur speciation
        iii. Synthetic Precipitation Leachate Procedure for source term modelling
    c. Soil assessment analysis:
        i. Particle size distribution analysis
        ii. pH, electrical conductivity, cation exchange capacity, bioavailable nutrient status, organic matter content and total metal concentrations.
4. Baseline soil, sediment assessments and geochemical assessments for acid rock drainage and metal leaching potential of the legacy tailings lithologies.
5. Provide mitigation measures and recommendations to inform legacy tailings management and river rehabilitation plans.
6. Technical memo reporting

3.0 Methodology

Consultants from SLR mobilised to the Trinity Metals mine sites from 13 to 25 July 2025 to undertake the specialist assessments. ~~Trinity~~ Rutongo is the largest concession within the Trinity Metals portfolio and consists of six mining sites namely, Gisanze, Karambo, Mahaza, Masoro, Gasambya and Nyanyumba. The SLR field team started their campaign at this concession which occurred from the 14th to 18th July to undertake the site scoping and sampling program.

3.1 Sampling Program

The SLR field team worked closely with the mines geology and environmental team members to undertake the specialist assessments. Their input was crucial in identifying the representative lithologies or rock types that are associated with the legacy tailings at each mine as well as, in identifying appropriate locations for soil and sediment sampling corresponding to surface water monitoring points for each site.

These monitoring points guided the SLR field team in identifying appropriate upstream and downstream areas from the mine footprint, for the river sediment sampling initiative. The downstream areas were also used to locate undisturbed areas for the visual soil assessment, classification and sample collection.

3.1.1 Legacy Tailings Sampling Protocol

Sampling of the legacy tailings piles on the Rutongo mines was facilitated with the assistance of the mine geologist. They assisted in identifying the legacy tailings lithologies that are representative of each rock type. The samples collected for analysis was largely determined by the degree of weathering and size of the sample.

After selecting the samples, they were described and their GPS coordinates recorded. Refer to Table 3-1 for a summary of the legacy tailings sample details and Figure 3-1 for the locations of the legacy tailings piles that were sampled at each site.

Table 3-1: Rutongo Mines Legacy Tailings Sample Summary

Mine	Sample ID	Latitude	Longitude	Description
Gasambya	GA-TS-10	1°47'44.5"S	30°03'05.5"E	Schist
	GA-TS-11	1°47'44.5"S	30°03'05.5"E	Quartzite
	GA-TS-12	1°47'44.5"S	30°03'05.5"E	Quartz vein
Gisanze	GS-TS-21	1°46'31.0"S	30°01'04.9"E	Quartzite
	GS-TS-22	1°46'31.0"S	30°01'04"E	Phyllite
	GS-TS-23	1°46'31.0"S	30°01'04"E	Quartz vein
Karambo	KE-LT-27	1°46'04.5"S	30°03'14.3"E	Fe rich quartz vein
	KE-LT-28	1°46'04.5"S	30°03'14.3"E	Quartz vein
	KE-LT-29	1°46'04.5"S	30°03'14.3"E	Phyllite
	KE-LT-30	1°46'04.5"S	30°03'14.3"E	Quartzite
Mahaza	MAH-TS-16	1°47'53.1"S	30°04'57.9"E	Quartz vein
	MAH-TS-17	1°47'53.1"S	30°04'57.9"E	Quartzite
	MAH-TS-18	1°47'53.1"S	30°04'57.9"E	Phyllite
Masoro	MAS-BV-05	1°49'25.7"S	30°02'44.9"E	Schist
	MAS-BV-06	1°49'25.7"S	30°02'44.9"E	Quartz vein
	MAS-BV-07	1°49'25.7"S	30°02'44.9"E	Quartzite
	MU-LT-39	1°55'30.8"S	30°20'20.9"E	Sandstone
	MU-LT-40	1°55'30.8"S	30°20'20.9"E	Quartz vein
Nyanyumba	NYA-SN-01	1°48'14"S	30°02'58"E	Quartz vein
	NYA-SN-02	1°48'14"S	30°02'58"E	Quartzite
	NYA-SS-03	1°48'22"S	30°03'06"E	Quartz vein
	NYA-SS-04	1°48'22"S	30°03'06"E	Quartzite

3.1.2 River Sediment Sampling Protocol

The river sediment sampling was undertaken in consultation with the mines environmental team to identify upstream and downstream sampling positions based on the surface water quality monitoring program. The SLR consultants assessed the locations in relation to the mines footprint as well as the presence of unauthorised (illegal) mining and quarrying activities within the vicinity of the identified locations.

Surface sediment samples from the riverbed was collected using a spade that was cleaned between sampling events. The sample description and GPS positions was recorded, and a photograph of the sample was taken. Refer to Table 3-2 for a summary of the river sediment sample details and Figure 3-2 for the locations of the sediment sampling points.

Table 3-2: Rutongo Mines River Sediment Sample Summary

Mine	Sample ID	Latitude	Longitude	River sediment locations
Gasambya	GASED-13	1°47'33.8"S	30°03'02.5"E	Upstream
	GASED-14	1°47'42.1"S	30°03'23.8"E	Downstream
Gisanze	GSED-20	1°46'40.2"S	30°00'54.0"E	Upstream
	GSED-24	1°46'23.2"S	30°01'11.5"E	Downstream
Karambo	KSED-25	1°46'11.4"S	30°03'01.6"E	Upstream
	KSED-26	1°46'07.7"S	30°03'21.1"E	Downstream
Mahaza	MAHSED-15	1°47'27.1"S	30°04'55"E	Upstream
	MAHSED-19	1°47'45.8"S	30°04'51.9"E	Downstream
Masoro	MASED-09	1°50'03.8"S	30°02'45"E	Downstream
	MASED-31	1°49'05.7"S	30°02'46.1"E	Upstream
Nyanyumba	NYASED-02	1°48'19.7"S	30°03'19.1"E	Downstream
	NYASED-03	1°48'19.7"S	30°03'20.9"E	Upstream

3.1.3 Soil Classification and Sampling Protocol

The soil assessment focused on determining the soil types of the downstream areas in relation to the mine footprint, as well as assessing the physical and chemical properties of the most downstream soil type to determine its potential to remediate any metal leaching and acid rock drainage risks that might be emanating from upstream activities. This was recommended as the downstream area are receptors for the migration of materials and contaminants from upstream activities which are predominately anthropogenic. Furthermore, these areas are often closer to human settlements or agricultural land use which can provide for long-term environmental monitoring data and potential remediation planning.

Once identified, notable site conditions and GPS coordinates were recorded. A handheld soil augur was used to extract soil cores and emptied onto sheets in the sequence of removal so that the soil profile could be constructed above ground.

Coring continued up to a depth of at least 0.5 m were feasible. The soil was then visually assessed based on its physical properties and master horizons were identified and recorded on the soil log sheet. After the visual assessment, a photograph of the soil profile was taken and a top-soil sample (0 – 30 cm depth) was collected and placed into a labelled zip lock bag at each observation point. Refer to for a summary of the soil observation details and Figure 3-3 for the locations of the soil observation points.

Table 3-3: Rutongo Mines Soil Observation Summary

Mine	Sample ID	Latitude	Longitude	Sample Depth (cm)	Note
Gasambya	GAS-01	1°47'40.1"S	30°03'21.9"E	0 - 30	Discarded
	GAS-02	1°47'50.6"S	30°03'36.6"E		Submitted
Gisanze	GSS-01	1°46'21.9"S	30°01'11.8"E		Discarded
	GSS-02	1°46'20.11"S	30°01'12.9"E		Submitted
Karambo	KSS-01	1°46'070"S	30°03'20.6"E		Discarded
	KSS-02	1°46'13.4"S	30°03'44.4"E		Submitted
Mahaza	MHS-01	1°47'25.5"S	30°04'55.8"E		Discarded
	MHS-02	1°47'44.3"S	30°04'54.0"E		Submitted
Masoro	MAS-01	1°49'57.2"S	30°02'39.8"E		Discarded
	MAS-02	1°50'05.3"S	30°02'42.5"E		Submitted
Nyanyumba	NYAS-01	1°48'18.3"S	30°03'05"E		Discarded
	NYAS-02	1°48'19.6"S	30°03'20.9"E		Submitted

Figure 3-1: Rutongo Mines Legacy Tailings Sampling Points

Figure 3-2: Rutongo Mines River Sediment Sampling Points

Figure 3-3: Rutongo Mines Soil Observation Points

3.2 Laboratory Analysis

3.2.1 Mineralogy: X-Ray Diffraction

Minerals are the building blocks of rocks. Mine drainage quality is generally a function of mineral dissolution (or precipitation) reactions that occur during the interaction of rocks with the atmosphere and water. X-ray Diffraction (XRD) analysis identifies the main crystalline mineral phases in each sample. XRD is conducted on whole-rock samples that have been crushed and ground into a powder. The powdered sample is then placed on a flat holder, which faces the X-ray beam. The X-rays are diffracted by the crystal planes in the minerals, with diffraction peaks at characteristic angles. The phases are identified by comparing the locations and intensities of the diffraction peaks with those of mineral reference standards (Price, 2009). Limitations of XRD include limited ability to identify non-crystalline minerals as well as minerals present in extremely low proportions.

3.2.2 Sulphur Speciation

The ABA tests assume that all sulphide (S^{2-}) minerals in a rock sample are acid-generating. Some of the sulphur in the rock may be present in non-acid-producing sulphates (SO_4^{2-}). If a significant part of the total sulphur occurs as sulphate sulphur instead of sulphide sulphur, the overall risk of acid generation is reduced. However, significant water quality impacts may result from the leaching of sulfate sulfur into local water resources.

3.2.3 Acid Base Accounting (ABA)

3.2.3.1 Acid Potential and Neutralisation Potential

Acid-Base Accounting is an internationally accepted analytical procedure developed to assess the acid-producing and acid-neutralising potential of rocks. The Acid Potential (AP) is calculated as the total sulphide sulphur content in per cent multiplied by 31.25, which is derived from the oxidation of sulphide minerals in a rock sample.

The Acid Neutralising Potential (NP) is a measure of the total acid a material can neutralise and is predominantly a result of neutralising bases, mostly carbonates, to a limited extent silicate minerals, as the latter have slow reaction kinetics. AP and NP are both reported as Kg CaCO3 /Tonne.

The ABA tests assume that all sulfide minerals in a rock sample are acid-generating. Some of the sulfur in the rock may be present in non-acid producing sulfates. If a significant part of the total sulfur occurs as sulfate sulfur instead of sulfide sulfur, the overall risk of acid generation is reduced.

3.2.3.2 Net Neutralization Potential

The difference between acid-generating mineral phases (AP) and acid-neutralising mineral phases (NP) is referred to as the net neutralisation potential (NNP). Thus, the NNP is calculated by subtracting the AP from the Acid NP as follows:

$$\mathbf{NNP = NP - AP}$$

Results are reported in kg of calcium carbonate per tonne of overburden (or parts per thousand). The NNP allows for the classification of the samples as potentially acid-generating or acid-consuming as follows:

- Negative NNP indicates the potential to generate acid.
- Positive NNP indicates excess acid-neutralising potential.

3.2.3.3 Neutralization Potential Ratio

Acid-Base Accounting data is also described using the neutralisation potential ratio (NPR). The NPR is calculated by dividing the NP by the AP as follows:

NPR = NP/AP

The NPR can be used to identify potentially acid-generating rocks as follows:

- NPR ratios larger than 2 indicate non-potentially acid generating (non-PAG);
- ratios between 1 and 2 are considered inconclusive / possibly acid-generating and
- NPR ratios below 1 indicate potential acid generation (PAG).

3.2.4 Synthetic Precipitation Leaching Procedure

The Synthetic Precipitation Leaching Procedure (SPLP) is a quick and inexpensive method to determine:

- The mobility/leachability of low volatility organic and inorganic analytes in liquids, soils, and wastes.
- The measure of desorption of contaminants from soil (rather than adsorption).
- The possibility of leaching metals into ground and surface waters.
- A site-specific impact to groundwater soil remediation standard.

Since the test uses custom pH levels to simulate rainfall in a particular geographic region, this test is often recommended over other methods when predicting leachate quality and risk to ground water.

Many factors can affect the leaching potential of organic constituents: pH, redox conditions, liquid-to-solid ratio, solubility, partitioning, presence of organic carbon, and non-aqueous phase extraction. Therefore, SPLP concentrations are used as input concentrations to Geochemical models to simulate realistic field conditions and produce more accurate source terms.

As part of this assessment, the SPLP results were subject to preliminary screening to identify constituents of potential concern (COPCs) by comparing the results to the following relevant water quality and effluent standards:

- International Finance Corporation (IFC) – Mining Effluent Guidelines (IFC, 2007);
- World Health Organisation (WHO) Guidelines for drinking-water quality (WHO, 2017);
- World Health Organisation (WHO) Guidelines on Recreational use (WHO, 2021);
- Rwanda Standard RS 109 (2009): Effluent standard, specifies the limits for the discharge of treated industrial wastewater effluent into the environment (RS 109);
- Rwanda Standards RS 188 (2013): Irrigation use, specifies the tolerance limits for water intended for irrigation purposes (RS 188); and
- Rwanda Standards RS 190 (2013): Livestock watering, specifies the characteristics, requirements to be used for livestock watering (RW 190).

3.2.5 Total Metal Concentrations and Geochemical Abundance Index (GAI)

The total metal concentration analyses were considered because it provides the overall composition of the material. The results were subject to preliminary screening to identify if any metal is a potential contaminant in the soils / sediments by comparing the results to the Soil Screening Value 1 (SSV1) threshold as promulgated in GN R 331 of 2014 in accordance with the National Norms and Standards for the Remediation of Contaminated Land and Soil Quality in the Republic of South Africa.

The SSV1 thresholds are applicable to soil quality values that are protective of both human health and eco-toxicological risk for multi-exposure pathways, inclusive of contaminant migration to the water resource.

As part of the assessment, the degree of elemental enrichment in the sediments was assessed by calculating the geochemical abundance index (GAI) for the analysed elements. The GAI compares the measured concentration of an element in a sample with the estimated average crustal abundance of the element (INAP, 2014)[1] using the following equation:

$$\mathbf{GAI = log_2}\left(\frac{Cn}{1.5 \times Bn}\right)$$

Where:

Cn is the measured concentration of the metal in the sediment sample

Bn is the average crustal abundance of the metal

1.5 is a correction factor for natural variability in background/average crustal values

For this assessment, the average crustal abundance in the earth's crust as per Smith and Huyck (1999)[2] were used as background values.

A GAI value of ≤0 indicates the element is present at a concentration similar or less than the average crustal abundance, implies no enrichment suggesting no contamination.

A GAI value of ≥3 implies significant enrichment suggesting potential contamination, and

A GAI value of ≥6 implies extreme enrichment suggesting likely contamination.

3.2.6 Particle Size Distribution Analysis of Soil / Sediments

The particle size distribution of a given material is an important physical parameter in quality control processes and research applications, because many other properties are directly related to it. Particle size distribution influences material properties like flow and conveying behaviour (for bulk materials), reactivity, abrasiveness, solubility, extraction and reaction behaviour. It is also an important parameter to consider when delineating the potential for migration of contaminants in an aqueous environment.

3.2.7 Cation Exchange Capacity and Bioavailable Nutrients of Soil

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil chemical property influencing soil structure stability, nutrient availability, pH buffering and the soil's reaction to fertilisers and scavenging of heavy metals.

The soil capacity to supply nutrients is termed soil nutrient bioavailability and is the ability of the soil system to supply essential plant nutrients for plant metabolism. Release of nutrients

[1] INAP (International Network for Acid Prevention). 2014. Global Acid Rock Drainage Guide (GARD Guide). http://www.gardguide.com/

[2] Smith, K.S. and Huyck, H.L.O. 1999. An Overview of the Abundance, Relative Mobility, Bioavailability, and Human Toxicity of Metals. In G.S. Plumlee and M.J. Logsdon (Eds.), The Environmental Chemistry of Mineral Deposits, Reviews in Economic Geology, Volume 6A, pp. 29-70.

from the solid phase to the soil solution is controlled by the physiochemical processes of desorption and dissolution. It is also a biochemical process by way of mineralization.

3.3 Geochemical Source Terms

The SPLP results will be used as input concentrations to generate leachate source terms for the site. Laboratory leachate results are only an indicator of site drainage water quality, due to the test conditions not fully representing field conditions, most especially the liquid to solid ratio and varying redox settings.

PHREEQC is a geochemical software which can be used to perform geochemical calculations to predict mineral speciation, surface complexation, ion exchange equilibria and kinetic reactions. PREEEQC includes thermodynamic databases for a wide range of inorganic parameters relevant to industrial water quality and the field conditions they are subject to.

The generated geochemical source terms (predicted analyte concentrations) can then be input into a groundwater model to predict the significance and extent of contamination. A comprehensive geochemical and geohydrological assessment will assist in gaining a better understanding of potential risks and how to minimise those risks in the context of the site.

3.3.1 Model Code

This assessment applies the pH, Redox, Equilibrium Code (PHREEQC) for hydrogeochemical modelling (Parkhurst and Appelo, 2013)[3].

PHREEQC is a versatile geochemical model initially developed in 1995 by the United States Geological Survey. It has undergone extensive use, testing and validation by third parties with version 3 released in January 2015. This assessment used version 3.4.0.12927 (released 9th November 2017).

PHREEQC can perform low-temperature aqueous geochemical calculations, including speciation, saturation indices, batch reaction and 1-dimensional transport calculations. PHREEQC can account for aqueous, mineral, gas, solid solution, surface complexation and ion exchange equilibria, as well as kinetic reactions.

It is widely used for environmental geochemical modelling because it is freely available, open source, and flexible. It includes thermodynamic databases for a wide range of inorganic parameters relevant to mine water quality.

3.3.2 Model Inputs

The key model inputs are the contact water quality determined from laboratory leach tests (Appendix A). The input data concentrations were adjusted to achieve a charge balance equilibrium (CBE) < 10%. Concentrations indicated as below detection limit were entered as one-half of the detection limit or omitted were practical.

It is assumed that the sediment materials have a field moisture capacity of about 20%. The column of waste material can only generate seepage if the water content exceeds this value. No analysis was conducted to confirm this.

[3] Parkhurst, D.L. and Appelo, C.A.J. (2013) Description of Input and Examples for PHREEQC Version 3—A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. US Geological Survey Techniques and Methods, Book 6, Chapter A43, 497 p. http://pubs.usgs.gov/tm/06/a43

3.3.3 Boundary Conditions

The model boundary conditions are summarised in Table 3-4 below.

Table 3-4: Model boundary conditions

Boundary Conditions	Description
Gas phase	It is assumed that there is little biological activity in the material and the CO_2(g) pressure was set to $10^{-3.5}$ atm.
Minerals	Based on the mineralogical analysis the pure phase that can react reversibly with the aqueous phase is Quartz, Muscovite, Kaolinite, Goethite, Palygorskite (Sepiolite) and Dravite. Mineral phases to simulate only precipitation reactions were added for each sample modelled if they were over saturated in the solution.
Adsorption surface	Metal cations can sorb to charged surfaces. In this simulation no such sorption was simulated.

3.3.4 Model Algorithm

The algorithm comprised the following:

1. For simulations were mixing of different solutions were required the solutions were proportioned according to the determined ratios.
2. Determine pore water quality by adjusting solid-liquid ratio of leach test to expected ratio at field capacity. This was done by modelling the removal of water from the solution.
3. Establish equilibrium composition of pore water in sediments, allowing relevant minerals to dissolve/precipitate.

3.3.5 Model Limitations

Predicting water qualities from an evaporation and settling setting, requires some assumptions and has limitations. The statistician George Box said: all models are wrong, but some models are useful (Box, 1976)[4]. This statement captures the essential truth that all model's approximate reality in that they reduce complex systems to a limited number of significant processes. How "useful" a model is depending on how closely the selected processes approximate reality.

Predicting the water qualities of complex systems demands assumptions. Even a rigorous sampling and analysis programme cannot precisely determine the physical and geochemical characteristics of the system. Nor can they precisely indicate how these characteristics may change over time.

Table 3-5 below summarises the key limitations of the input data and the hydrogeochemical model used for this assessment.

[4] George E. P. Box. "Science and Statistics." Journal of the American Statistical Association, vol. 71, no. 356, 1976, pp. 791–99. JSTOR, https://doi.org/10.2307/2286841. Accessed 2 Dec. 2025.

Table 3-5: Model limitations

No	Limitations	Description
1	Predicting field scale water quality from lab scale test results is an approximation.	Leaching of salts and metals at the field scale is variable in time and controlled by factors not fully applied at the lab scale. Amongst others, these factors include temperature, evaporation, nature of the leaching solution, the solution to solid ratio, solution-solid contact time and particle size of the solid. The modelled quality of water due to interaction with tailings/slimes or waste is an informed estimate.
2	The geochemical database is relevant to the system being modelled.	Hydrogeochemical modelling uses the inherently uncertain laboratory results and water qualities as inputs. These are processed using thermodynamic data determined in the laboratory on ideal materials and solutions. The laboratory determined constants may not be directly applicable to the materials, solutions, and chemical context of the waste material. The llnl.dat database was used for the model.
3	The modelling assumes thermodynamic equilibrium in the model system.	In the field, all chemical components are subject to kinetic variation and the system might, at best, be in a state of quasi equilibrium. This may suggest that attempts to simulate or predict the state of these complex systems have questionable value. However, geochemical evaluations of natural and mine waters over the last few decades have shown that the equilibrium assumption is a powerful tool that in many circumstances produces results that accurately describe the general chemistry of such waters.
4	Adsorption surface	Metal cations can sorb to charged surfaces. There is no data to quantify either these surfaces, or their effect on water quality. Cation sorption linked to the amount of ferrihydrite precipitating was not modelled.

Considering the uncertainties outlined above, the available information is sufficient to provide the preliminary estimated seepage quality presented in this report. However, even though this report presents deterministic concentration values, these should be viewed as first-order approximations. As such, the predicted concentrations in this report indicate the likely order of magnitude concentrations.

4.0 River Sediment Results and Interpretations

4.1 Particle Size Distribution

Typically, downstream locations are characterised by a higher distribution of fine fractions like silt and clay whereas upstream locations are characterised by a larger distribution of coarse to medium fractions like gravel, cobble, pebbles and sand.

It is also established that there is a connection between sediment particle size and contamination, and it is suggested that downstream areas are likely to be more impacted than upstream locations. This is attributed to the accumulation of finer particles in downstream locations which can react more effectively due to their larger surface areas compared to coarser fractions. This can cause contamination concerns, especially during dry seasons where water flow is low but has enough energy to transport and deposit fine sediments downstream which accumulate and can serve as contamination zones.

Table 4-1 below shows the particle size distribution of the Rutongo mines river sediment samples respectively.

On average, the upstream sediment samples are characterised by the highest gravel fraction and lowest silt fraction, with minor to negligible differences in the clay fractions between the river sediment sampling positions. Furthermore, the sand fraction (i.e. medium particle size) is the dominant particle size fraction in terms of distribution for most of the sediment sampling position which suggests that the hydrological functioning of the river systems has been altered.

Table 4-1: Particle Size Distribution of the Rutongo Mines River Sediment Materials

Mine	Sample ID	Stream position	Gravel (2 - 75 mm)	Sand (0.05 - 2 mm)	Silt (0.002 - 0.05 mm)	Clay (< 0.002 mm)
			%	%	%	%
Nyanyumba	NYASED-03	Upstream	36	58	5	1
	NYASED-02	Downstream	10	82	7	1
Masoro	MASED-31	Upstream	5	81	10	4
	MASED-09	Downstream	41	55	4	-
Gasambya	GASED-13	Upstream	57	36	5	2
	GASED-14	Downstream	29	70	1	-
Mahaza	MAHSED-15	Upstream	-	45	40	15
	MAHSED-19	Downstream	-	25	60	15
Gisanze	GSED-20	Upstream	-	63	30	7
	GSED-24	Downstream	-	25	64	11
Karambo	KSED-25	Upstream	2	84	13	1
	KSED-26	Downstream	51	32	16	1

Note: “-“implies no value.

4.2 Mineralogy

Refer to Table 4-2 below for an overview of the mineralogical composition of the Rutongo mines river sediment samples.

The XRD results show that Quartz is the dominant mineral in the river sediment samples with major to minor proportions of Muscovite varying between 0.65 to 36.82 %. There are also minor proportions of Kaolinite varying between 0.77 to 10.97% as well as Schorl which varies between 0.29 to 4.6% in the sediments. Furthermore, minor to trace amounts of Hematite in present in most of the river sediments which varies between 0.05 to 4.45%.

In terms of the ability of the minerals that were identified in the river sediments to remediate metal leaching and acid rock drainage risks, the following is noted:

Quartz has a very limited ability to assist in remediating metal leaching and acid rock drainage risks. This is largely because it is chemically inert, has very few reactive surface sites to facilitate surface complexation and metal adsorption and does not contain neutralizing capacity.

Schorl also has a limited ability to remediate ARD because it is chemically stable and lacks acid neutralizing capacity. Conversely, it is a cyclosilicate mineral that contains borosilicate rings with surface hydroxyl groups as part of its structure which can serve as sites for metal adsorption and therefore has the ability to remediate metal leaching.

Muscovite has a limited potential to remediate acid rock drainage mainly because of its slow dissolution kinetics compared to the rapid acid generating potential of Pyrite oxidation. Furthermore, it has minimal potential to remediate metal leaching due to it relatively low surface area which can facilitate metal adsorption.

Kaolinite has the potential for remediating metal leaching because of its surface chemistry and structural properties. Kaolinite surfaces are also dominated by hydroxyl groups which can bind metal ions through electrostatic bonds.

Hematite is very effective in remediating metal leaching due to the abundance of hydroxyl groups on its surface that can bind several metal ions through adsorption and inner-sphere surface complexation. Furthermore, it has an affinity for oxyanions and will strongly adsorb arsenate and chromate. It can limit the oxidation of Pyrite and consequently reduce the formation of ARD.

Due to the presence of Hematite, Schorl, Kaolinite and Muscovite in the sediments, they can sequester metals and metalloids that are mobilised due to historic and current mining activities occurring in the vicinity of the rivers. This suggests that the sediments are likely to show an enrichment / accumulation of various metals that could exceed average crustal abundances or background level values.

Table 4-2: Rutongo Mines River Sediment XRD Mineralogy Results

Mineral	Formula	Mine											
		Nyanyumba		Masoro		Gasambya		Mahaza		Gisanze		Karambo	
		Sample ID											
		NYASED-03	NYASED-02	MASED-31	MASED-09	GASED-13	GASED-14	MAHSED-15	MAHSED-19	GSED-20	GSED-24	KSED-25	KSED-26
		Stream Position											
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
		Composition (%)											
Quartz	SiO_2	91.85	90.35	84.92	90.92	80.48	96.99	69.61	59.98	78.33	48.95	91.86	86.76
Hematite	Fe_2O_3	2	0.5	0.49	0.45	4.45	0.93	-	-	0.43	0.53	0.15	0.05
Kaolinite	$Al_2Si_2O_5(OH)_4$	3.06	2.10	2.81	1.76	9.13	1.17	7.21	10.97	2.07	8.5	1.23	0.77
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	2.35	5.38	8.53	4.16	4.15	0.65	23.18	28.12	15.82	36.82	2.16	9.03
Schorl	$NaFe_3Al_6(BO_3)_3(Si_6O_{18})(OH)_4$	0.73	1.67	3.25	2.70	1.79	0.26	-	0.94	3.35	5.2	4.6	3.39

4.3 Synthetic Leaching Precipitation Procedure

The Synthetic Precipitation Leaching Procedure (SPLP) results are provided in Table 4-3. Based on the results, the following analytes exceeded applicable local and international water quality and effluent standard limits and could potentially be COPCs.

Referring to the screening tables below, the following exceedances were reported for the:

Nyanyumba Mine:

Upstream sediment (NYASED-03)

a) Mn (WHO Drinking, RS Irrigation and RS Livestock)

Downstream sediment (NYASED-02)

a) Fe (RS Livestock)

b) Mn (WHO Drinking)

c) pH (IFC and RS Livestock)

Masoro Mine:

Upstream sediment (MASED-31)

a) pH (IFC and RS Livestock)

Downstream sediment (MASED-09)

a) As and Mn (WHO Drinking)

b) Fe (IFC, RS Effluent, Irrigation and Livestock)

c) pH (IFC and RS Livestock)

Gasambya Mine:

Upstream sediment (GASED-13)

a) Fe (RS Livestock)

b) pH (IFC and RS Livestock)

Downstream sediment (GASED-14)

a) Mn (WHO Drinking)

b) pH (IFC and RS Livestock)

Mahaza Mine:

Upstream sediment (MAHSED-15)

a) Mn (WHO Drinking, RS Irrigation and Livestock)

b) pH (IFC and RS Livestock)

Downstream sediment (MAHSED-19)

a) Mn (WHO Drinking, RS Irrigation and Livestock)

b) pH (IFC and RS Livestock)

Gisanze Mine:

Upstream sediment (GSED-20)

a) Fe (IFC, RS Effluent, Irrigation and Livestock)
b) Mn (WHO Drinking, RS Irrigation and Livestock)
c) Pb (WHO Drinking)

Downstream sediment (GSED-24)

a) Fe (IFC, RS Effluent and Livestock)
b) Mn (WHO Drinking and RS Irrigation)
c) pH (IFC and RS Livestock)

Karambo Mine:

Upstream sediment (KSED-25)

a) Fe (RS Livestock)

Downstream sediment (KSED-26)

a) As (WHO Drinking)
b) Fe (RS Livestock)
c) Mn (WHO Drinking)
d) pH (IFC and RS Livestock)

Table 4-3: Rutongo Mines River Sediment SPLP Screening Results

Mine	Stream Position	Analytes	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr (total)	Cr(VI)	Cs	Cu	Dy	Er	Eu	Fe	Ga
		Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
		1. WHO: Drinking Water (2022)			**0.01**		**2.4**	**1.3**				**0.003**			**0.05**		**2**						
		2. WHO: Recreational Use (2021)		**18**	**0.2**										**1**		**40**						
		3. IFC: Mining Effluent			**0.1**							**0.05**						**0.3**				**2**	
		4. RS 109 of 2009: Effluent Standards				**0.01**												**3**				**3.5**	
		5. RS 188 (2013): Irrigation Use			**5**	**0.1**			**0.1**			**0.01**		**0.05**	**0.1**			**0.2**				**5**	
		6. RS 190 (2013): Livestock Watering			**5**	**2**					**200**	**0.5**		**1**	**1**			**0.5**				**0.3**	
Nyanyumba	Upstream	NYASED-03	0.005	0.103	0.002	0.001	0.013	0.085	0.013	0.001	4.02	0.001	0.001	0.031	0.013	0.005	0.005	0.005	0.001	0.001	0.001	0.101	0.007
	Downstream	NYASED-02	0.009	1.07	0.004	0.001	0.013	0.013	0.013	0.001	1.48	0.001	0.006	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	1.51	0.002
Masoro	Upstream	MASED-31	0.016	0.050	0.001	0.001	0.013	0.013	0.013	0.001	0.997	0.001	0.001	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	0.058	0.001
	Downstream	MASED-09	0.003	1.09	0.012	0.001	0.013	0.030	0.013	0.001	1.60	0.001	0.009	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	5.84	0.003
Gasambya	Upstream	GASED-13	0.007	0.428	0.002	0.001	0.013	0.013	0.013	0.001	1.34	0.001	0.002	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	0.307	0.001
	Downstream	GASED-14	0.005	0.050	0.003	0.001	0.013	0.013	0.013	0.001	1.17	0.001	0.001	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	0.013	0.001
Mahaza	Upstream	MAHSED-15	0.002	0.050	0.003	0.001	0.013	0.052	0.013	0.001	6.74	0.001	0.001	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	0.088	0.004
	Downstream	MAHSED-19	0.001	0.050	0.002	0.001	0.013	0.060	0.013	0.001	11.27	0.001	0.001	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	0.093	0.005
Gisanze	Upstream	GSED-20	0.001	2.34	0.007	0.001	0.013	0.132	0.013	0.001	3.75	0.001	0.018	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	25.8	0.011
	Downstream	GSED-24	0.023	1.92	0.010	0.001	0.013	0.033	0.013	0.001	2.50	0.001	0.008	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	4.33	0.005
Karambo	Upstream	KSED-25	0.010	0.303	0.002	0.001	0.013	0.013	0.013	0.001	1.40	0.001	0.002	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	0.403	0.001
	Downstream	KSED-26	0.006	0.279	0.019	0.001	0.013	0.013	0.013	0.001	1.33	0.001	0.002	0.013	0.013	0.005	0.005	0.005	0.001	0.001	0.001	0.497	0.002

Mine	Stream Position	Analytes	Gd	Ge	Hf	Hg	Ho	In	Ir	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb	Nd	Ni	Os	P
		Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
		1. WHO: Drinking Water (2022)				**0.006**									**0.08**		**50**			**0.07**		
		2. WHO: Recreational Use (2021)													**8**					**1.4**		
		3. IFC: Mining Effluent				**0.002**														**0.5**		
		4. RS 109 of 2009: Effluent Standards				**0.002**														**3**		
		5. RS 188 (2013): Irrigation Use										**2.5**			**0.2**	**0.01**	**3**			**0.2**		
		6. RS 190 (2013): Livestock Watering				**0.05**				**20**				**80**	**0.5**		**100**			**1**		**1**
Nyanyumba	Upstream	NYASED-03	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.00	0.001	0.002	0.001	1.21	3.14	0.013	0.500	0.001	0.001	0.013	0.001	0.001
	Downstream	NYASED-02	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.678	0.003	0.001	0.001	0.500	0.140	0.013	0.500	0.001	0.002	0.013	0.001	0.001
Masoro	Upstream	MASED-31	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.250	0.001	0.002	0.001	0.500	0.076	0.013	0.500	0.001	0.001	0.013	0.001	0.001
	Downstream	MASED-09	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.602	0.004	0.001	0.001	0.500	0.179	0.013	0.500	0.001	0.003	0.013	0.001	0.001
Gasambya	Upstream	GASED-13	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.732	0.001	0.001	0.001	0.500	0.044	0.013	0.500	0.001	0.001	0.013	0.001	0.001
	Downstream	GASED-14	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.250	0.001	0.001	0.001	0.500	0.096	0.013	0.500	0.001	0.001	0.013	0.001	0.001
Mahaza	Upstream	MAHSED-15	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.54	0.001	0.002	0.001	2.48	1.92	0.013	0.500	0.001	0.001	0.013	0.001	0.001
	Downstream	MAHSED-19	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.99	0.001	0.003	0.001	4.13	2.81	0.013	0.500	0.001	0.001	0.013	0.001	0.001
Gisanze	Upstream	GSED-20	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.29	0.007	0.001	0.001	0.951	1.74	0.013	0.500	0.001	0.006	0.013	0.001	0.346
	Downstream	GSED-24	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.02	0.004	0.001	0.001	0.500	0.314	0.013	0.500	0.001	0.003	0.013	0.001	0.034
Karambo	Upstream	KSED-25	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.250	0.001	0.001	0.001	0.500	0.056	0.013	0.500	0.001	0.001	0.013	0.001	0.001
	Downstream	KSED-26	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.950	0.001	0.003	0.001	0.500	0.153	0.013	0.500	0.001	0.001	0.013	0.001	0.001

Mine	Stream Position	Analytes	Pb	Pd	Pr	Pt	Rb	Rh	Ru	Sb	Sc	Se	Si	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl
		Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
		1. WHO: Drinking Water (2022)	**0.01**							**0.02**		**0.04**										
		2. WHO: Recreational Use (2021)																				
		3. IFC: Mining Effluent	**0.2**																			
		4. RS 109 of 2009: Effluent Standards	**0.1**									**0.02**										
		5. RS 188 (2013): Irrigation Use	**5**									**0.02**										
		6. RS 190 (2013): Livestock Watering	**0.05**									**0.5**										
Nyanyumba	Upstream	NYASED-03	0.001	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001	1.36	0.001	0.001	0.041	0.001	0.001	0.001	0.001	0.002	0.001
	Downstream	NYASED-02	0.004	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.004	1.67	0.001	0.001	0.013	0.001	0.001	0.001	0.001	0.012	0.001
Masoro	Upstream	MASED-31	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.10	0.001	0.001	0.013	0.001	0.001	0.001	0.002	0.003	0.001
	Downstream	MASED-09	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.94	0.001	0.001	0.013	0.001	0.001	0.001	0.001	0.021	0.001
Gasambya	Upstream	GASED-13	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	2.09	0.001	0.001	0.013	0.001	0.001	0.001	0.001	0.001	0.001
	Downstream	GASED-14	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.006	1.09	0.001	0.001	0.013	0.001	0.001	0.001	0.001	0.001	0.001
Mahaza	Upstream	MAHSED-15	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	3.05	0.001	0.001	0.069	0.001	0.001	0.001	0.001	0.001	0.001
	Downstream	MAHSED-19	0.001	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.003	3.43	0.001	0.001	0.112	0.001	0.001	0.001	0.001	0.001	0.001
Gisanze	Upstream	GSED-20	0.016	0.001	0.002	0.001	0.006	0.001	0.001	0.001	0.001	0.001	6.01	0.001	0.001	0.037	0.001	0.001	0.001	0.004	0.053	0.001
	Downstream	GSED-24	0.008	0.001	0.001	0.001	0.004	0.001	0.001	0.001	0.001	0.001	2.47	0.001	0.001	0.013	0.001	0.001	0.001	0.002	0.016	0.001
Karambo	Upstream	KSED-25	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.16	0.001	0.001	0.013	0.001	0.001	0.001	0.001	0.002	0.001
	Downstream	KSED-26	0.008	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	1.15	0.001	0.001	0.013	0.001	0.001	0.001	0.001	0.002	0.001

Mine	Stream Position	Analytes	Tm	U	V	W	Y	Yb	Zn	Zr	pH	EC	TDS	Tot Alk	Cl	SO4	NO3	NO2	F	Free NH3	Ortho-P	Total Cn
		Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*		*mS/m*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
		1. WHO: Drinking Water (2022)		**0.03**													**50**	**3**	**1.5**			
		2. WHO: Recreational Use (2021)																				
		3. IFC: Mining Effluent							**0.5**		**6-9**											**1**
		4. RS 109 of 2009: Effluent Standards							**5**		**5-9**		**2000**									
		5. RS 188 (2013): Irrigation Use			**0.1**				**2**				**450**				**5**		**1**			
		6. RS 190 (2013): Livestock Watering		**0.2**	**0.1**				**25**		**6-9**		**1000**	**500**	**100**	**250**	**25**	**10**				
Nyanyumba	Upstream	NYASED-03	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	5.00	6.20	42	12	1	17	0.050	0.025	0.100	0.100	0.050	0.035
	Downstream	NYASED-02	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	6.00	1.20	5	12	2	2	0.200	0.025	0.100	0.050	0.050	0.035
Masoro	Upstream	MASED-31	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	5.20	1.30	5	16	1	1	0.100	0.025	0.100	0.050	0.050	0.035
	Downstream	MASED-09	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	5.70	1.20	5	16	3	1	0.050	0.025	0.100	0.050	0.050	0.035
Gasambya	Upstream	GASED-13	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	5.80	1.20	5	8	2	1	0.100	0.025	0.100	0.050	0.050	0.035
	Downstream	GASED-14	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	5.20	1.70	11	12	1	1	0.100	0.025	0.100	0.050	0.050	0.035
Mahaza	Upstream	MAHSED-15	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	5.20	8.10	54	12	1	28	0.050	0.025	0.100	0.050	0.050	0.035
	Downstream	MAHSED-19	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	5.00	13.20	88	8	1	59	0.050	0.025	0.100	0.100	0.050	0.035
Gisanze	Upstream	GSED-20	0.001	0.001	0.013	0.001	0.002	0.001	0.025	0.003	6.00	2.80	19	12	2	5	0.100	0.025	0.100	0.050	0.050	0.035
	Downstream	GSED-24	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.005	5.50	1.80	12	16	2	3	0.050	0.025	0.100	0.050	0.050	0.035
Karambo	Upstream	KSED-25	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	6.10	1.10	5	12	2	1	0.100	0.025	0.100	0.050	0.050	0.035
	Downstream	KSED-26	0.001	0.001	0.013	0.001	0.001	0.001	0.013	0.001	5.60	1.70	11	12	1	2	0.200	0.025	0.100	0.100	0.050	0.035

Note: Values in grey text represent below detection limit values.

4.4 Total Metal Concentrations (SSV) and Geochemical Abundance Index

Table 4-4 shows the total metal concentration results of the sediment samples that were screened against the SSV1 (all land uses) thresholds to assess if any element is a potential contaminant. Based on the screening results, the following exceedances were reported for:

<u>Nyanyumba Mine:</u>

Upstream and Downstream sediments

- As and Pb

<u>Masoro Mine:</u>

Upstream sediment

- As, Cu and Pb

Downstream sediment

- As

<u>Gasambya Mine:</u>

Upstream sediment

- As, Cu, Pb and V

Downstream sediment

- As

<u>Mahaza Mine:</u>

Upstream sediment

- As and Pb

Downstream sediment

- As, Cu and Pb

<u>Gisanze Mine:</u>

Upstream and downstream sediment

- As and Pb

<u>Karambo Mine:</u>

Upstream sediment

- As and Pb

Downstream sediment

- As, Cu and Pb

The exceedances of the SSV1 limits for the various metals in the sediments show that anthropogenic activities have likely impacted the rivers in the vicinity of the Rutongo mines respectively. This is likely attributed to historic and current panning activities, runoff from the legacy tailings piles and illegal mining activities along the rivers.

Table 4-5 shows the GAI values that were compared to the estimated average crustal abundance of the various elements analysed to assess the significance of elemental enrichment in the sediments and determine the likelihood of contamination. Based on the calculated GAI values of the metals that were analysed, the following is noted:

<u>Nyanyumba Mine:</u>

Upstream sediment

- B, Bi, and Se show a GAI>3 (implying significant enrichment and potential contamination)
- As shows a GAI>6 (implying extreme enrichment and likely contamination)

Downstream sediment

- B and Se show a GAI>3 (implying significant enrichment and potential contamination)
- As shows a GAI>6 (implying extreme enrichment and likely contamination)

<u>Masoro Mine:</u>

Upstream sediment

- B and Se show a GAI>3 (implying significant enrichment and potential contamination)
- As shows a GAI>6 (implying extreme enrichment and likely contamination)

Downstream sediment

- As and B show a GAI>3 (implying significant enrichment and potential contamination)

<u>Gasambya Mine:</u>

Upstream sediment

- B shows a GAI>3 (implying significant enrichment and potential contamination)
- As shows a GAI>6 (implying extreme enrichment and likely contamination)

Downstream sediment

- B and Se show a GAI>3 (implying significant enrichment and potential contamination)
- As shows a GAI>6 (implying extreme enrichment and likely contamination)

<u>Mahaza Mine:</u>

Upstream sediment

- As and B shows a GAI>3 (implying significant enrichment and potential contamination)

Downstream sediment

- As, B and W show a GAI>3 (implying significant enrichment and potential contamination)

<u>Gisanze Mine:</u>

Upstream and downstream sediments

- As and Sn show a GAI>3 (implying significant enrichment and potential contamination)
- B shows a GAI>6 (implying extreme enrichment and likely contamination)

<u>Karambo Mine:</u>

Upstream sediment

- As shows a GAI>3 (implying significant enrichment and potential contamination)
- B shows a GAI>6 (implying extreme enrichment and likely contamination)

Downstream sediment

- Ag, Bi and Sn show a GAI>3 (implying significant enrichment and potential contamination)
- As, B and Pd shows a GAI>6 (implying extreme enrichment and likely contamination)

Table 4-4: Rutongo Mines River Sediment Total Metal Concentration Screening Results

Mine	Stream Position	Analytes	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr (total)	Cs	Cu	Dy	Er	Eu	Fe	Ga
		Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
		SSV1 (All Land Uses Protective of the Water Resource)			**5.8**							**7.5**		**300**			**16**					
Nyanyumba	Upstream	NYASED-03	0.200	15543	401	0.200	207	82	5	10.151	200	0.200	2.39	5	115	1.22	11	0.200	0.200	0.200	61397	17
	Downstream	NYASED-02	0.200	15020	226	0.200	440	111	5	0.818	664	0.200	5.39	5	130	1.94	12	0.200	0.200	0.200	27618	18
Masoro	Upstream	MASED-31	0.200	15839	326	0.200	776	41	5	0.894	200	0.200	2.32	5	65	1.53	22	0.200	0.200	0.200	39724	16
	Downstream	MASED-09	0.200	13059	165	0.200	860	38	5	0.796	200	0.200	1.38	5	44	0.578	12	0.200	0.200	0.200	28214	12
Gasambya	Upstream	GASED-13	0.200	18382	1443	0.200	368	45	5	0.810	200	0.200	5.49	5	261	0.799	25	0.200	0.200	0.200	104466	19
	Downstream	GASED-14	0.200	8128	296	0.200	632	28	5	1.787	200	0.200	0.200	5	211	1.34	7	0.200	0.200	0.200	35108	6
Mahaza	Upstream	MAHSED-15	0.200	29588	60	0.200	608	96	5	0.647	200	0.200	0.200	5	694	0.733	15	0.200	0.200	0.200	28168	16
	Downstream	MAHSED-19	0.200	51258	66	0.200	582	162	5	0.696	200	0.200	0.200	5	126	0.774	19	0.200	0.200	0.200	33481	16
Gisanze	Upstream	GSED-20	0.200	24758	67	0.200	1463	64	5	1.971	200	0.200	0.200	5	83	4.22	12	0.200	0.200	0.200	37815	14
	Downstream	GSED-24	0.200	32209	93	0.200	1418	44	5	1.448	200	0.200	0.200	5	138	4.76	12	0.200	0.200	0.200	34147	20
Karambo	Upstream	KSED-25	0.200	13625	61	0.200	2051	61	5	0.620	200	0.200	0.200	5	158	1.12	7	0.200	0.200	0.200	22354	9
	Downstream	KSED-26	5.761	16414	376	0.200	1707	135	5	3.079	200	0.200	0.644	5	238	4.43	17	0.200	0.200	0.200	33764	16

Mine	Stream Position	Analytes	Gd	Ge	Hf	Hg	Ho	In	Ir	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb	Nd	Ni	Os	P
		Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
		SSV1 (All Land Uses Protective of the Water Resource)				**1**									**740**					**91**		
Nyanyumba	Upstream	NYASED-03	0.200	2.79	5.32	0.200	0.200	0.200	0.200	3894	0.404	20.7	0.200	0.200	92	5	200	9.8	0.480	5	0.200	1307
	Downstream	NYASED-02	0.200	2.71	5.69	0.200	0.200	0.200	0.200	5466	0.200	30.6	0.200	732	384	5	200	14.5	0.576	5	0.200	1149
Masoro	Upstream	MASED-31	0.200	3.59	6.26	0.200	0.200	0.200	0.200	6129	0.200	33.8	0.200	460	122	5	200	24.0	0.200	11.4	0.200	1184
	Downstream	MASED-09	0.200	2.60	7.80	0.200	0.200	0.200	0.200	3758	0.200	15.5	0.200	519	100	5	200	18.3	0.200	5	0.200	1237
Gasambya	Upstream	GASED-13	0.200	2.16	4.52	0.200	0.200	0.200	0.200	3839	0.843	14.0	0.200	0.200	46	5	200	13.1	0.809	5	0.200	1297
	Downstream	GASED-14	0.200	1.87	4.84	0.200	0.200	0.200	0.200	1582	0.200	12.6	0.200	0.200	76	5	200	6.2	0.200	14.7	0.200	1148
Mahaza	Upstream	MAHSED-15	0.200	2.28	13.00	0.200	0.200	0.200	0.200	14927	0.200	31.7	0.200	677	204	5	773	22.3	0.200	19.3	0.200	1266
	Downstream	MAHSED-19	0.200	2.12	12.56	0.200	0.200	0.200	0.200	18519	0.200	34.9	0.200	739	283	5	906	27.7	0.200	12.3	0.200	1368
Gisanze	Upstream	GSED-20	0.200	1.59	6.50	0.200	0.200	0.200	0.200	11467	0.200	24.7	0.200	663	276	5	702	17.3	0.200	12.1	0.200	1453
	Downstream	GSED-24	0.200	2.31	11.06	0.200	0.200	0.200	0.200	24143	0.200	73.9	0.200	472	105	5	905	23.2	0.200	14.7	0.200	1255
Karambo	Upstream	KSED-25	0.200	1.60	6.23	0.200	0.200	0.200	0.200	4501	0.200	31.1	0.200	626	133	5	772	9.0	0.200	5	0.200	1242
	Downstream	KSED-26	0.200	2.67	5.95	0.200	0.200	0.200	0.200	7370	0.200	61.5	0.200	599	121	5	415	6.8	0.700	13.2	0.200	1473

Mine	Stream Position	Analytes	Pb	Pd	Pr	Pt	Rb	Rh	Ru	Sb	Sc	Se	Si	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl
		Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
		SSV1 (All Land Uses Protective of the Water Resource)	**20**																			
Nyanyumba	Upstream	NYASED-03	25.71	0.200	0.200	0.200	12.5	0.200	0.200	0.200	5.3	2.54	275132	0.200	12.2	5	1.24	0.200	0.200	6.00	2611	0.200
	Downstream	NYASED-02	23.70	0.200	0.200	0.200	14.4	0.200	0.200	0.200	5.5	6.08	283524	0.200	20.1	11.7	1.86	0.200	0.200	3.98	3768	0.200
Masoro	Upstream	MASED-31	23.54	0.200	0.200	0.200	13.9	0.200	0.200	0.200	4.9	6.16	261608	0.200	26.9	5	2.16	0.200	0.200	2.83	5927	0.200
	Downstream	MASED-09	16.86	0.200	0.200	0.200	6.0	0.200	0.200	0.200	4.2	0.200	278116	0.200	17.3	5	1.91	0.200	0.200	3.93	5384	0.200
Gasambya	Upstream	GASED-13	86.62	0.200	0.200	0.200	11.9	0.200	0.200	0.793	6.7	0.200	223532	0.200	10.4	5	1.24	0.200	0.200	6.59	2549	0.200
	Downstream	GASED-14	16.61	0.200	0.200	0.200	8.6	0.200	0.200	0.200	3.3	1.43	255569	0.200	7.9	5	5.63	0.200	0.200	3.83	1973	0.200
Mahaza	Upstream	MAHSED-15	37.93	0.200	0.200	0.200	20.0	0.200	0.200	0.200	5.7	0.200	218393	0.200	12.7	5	6.37	0.200	0.200	2.13	7673	0.734
	Downstream	MAHSED-19	36.43	0.200	0.200	0.200	23.3	0.200	0.200	0.200	6.1	0.200	185855	0.200	15.6	10.6	6.67	0.200	0.200	1.93	7531	0.899
Gisanze	Upstream	GSED-20	26.66	0.200	0.200	0.200	46.5	0.200	0.200	0.200	3.6	0.200	222090	0.200	43.8	5	9.62	0.200	0.200	1.97	5531	1.19
	Downstream	GSED-24	35.37	0.200	0.200	0.200	47.4	0.200	0.200	0.200	6.1	0.67	180677	0.200	62.2	5	8.33	0.200	0.200	1.18	7376	1.51
Karambo	Upstream	KSED-25	40.17	0.200	0.200	0.200	9.1	0.200	0.200	0.200	3.1	0.200	272563	0.200	16.2	5	4.24	0.200	0.200	2.82	4589	0.200
	Downstream	KSED-26	142.66	2.26	0.200	0.200	27.3	0.200	0.200	0.200	7.3	0.200	231278	0.200	34.9	16.6	5.33	0.200	0.200	3.62	2060	0.617

Mine	Stream Position	Analytes	Tm	U	V	W	Y	Yb	Zn	Zr
		Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
		SSV1 (All Land Uses Protective of the Water Resource)			**150**				**240**	
Nyanyumba	Upstream	NYASED-03	0.200	1.98	134.55	2.59	0.200	0.200	17.5	142
	Downstream	NYASED-02	0.200	2.09	67.65	2.51	0.200	0.200	25.8	143
Masoro	Upstream	MASED-31	0.200	2.40	98.81	2.85	0.200	0.200	37.0	174
	Downstream	MASED-09	0.200	2.42	51.16	2.05	0.200	0.200	28.5	218
Gasambya	Upstream	GASED-13	0.200	3.81	212.33	2.43	0.200	0.200	27.5	126
	Downstream	GASED-14	0.200	1.36	80.31	0.99	0.200	0.200	5.9	78
Mahaza	Upstream	MAHSED-15	0.200	3.30	102.64	6.63	0.200	0.200	32.6	241
	Downstream	MAHSED-19	0.200	3.43	113.03	12.54	0.200	0.200	43.5	234
Gisanze	Upstream	GSED-20	0.200	2.50	65.19	7.32	0.200	0.200	32.3	118
	Downstream	GSED-24	0.200	2.64	127.05	4.90	0.200	0.200	28.6	211
Karambo	Upstream	KSED-25	0.200	1.82	47.79	4.26	0.200	0.200	19.7	111
	Downstream	KSED-26	0.200	2.48	56.34	9.56	0.200	0.200	36.7	55

Note: Values in grey text represent below detection limit concentrations

Table 4-5: Rutongo Mines River Sediment GAI Screening Results

Mine	Stream Position	Analytes	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr (total)	Cs	Cu	Dy	Er	Eu	Fe	Ga
		Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
		Crustal Abundance (Smith and Huyck)	**0.07**	**80000**	**2**	**0.004**	**10**	**430**	**3**	**0.2**	**3000**	**0.18**	**45**	**25**	**200**	**3**	**60**	**4.5**				
		1. GAI ≥ 3: Significant enrichment (possible contamination)																				
		2. GAI ≥ 6: Extreme enrichment (likely contamination)																				
Nyanyumba	Upstream	NYASED-03	0.20	-2.95	7.06	0.20	3.78	-2.98	5	5.08	200.00	0.20	-4.82	-2.91	-1.39	-1.89	-2.99	0.20	0.20	0.20	-0.29	-0.58
	Downstream	NYASED-02	0.20	-3.00	6.23	0.20	4.87	-2.54	5	1.45	-2.76	0.20	-3.65	-2.91	-1.21	-1.21	-2.88	0.20	0.20	0.20	-1.44	-0.48
Masoro	Upstream	MASED-31	0.20	-2.92	6.76	0.20	5.69	-3.98	5	1.58	200.00	0.20	-4.87	-2.91	-2.20	-1.56	-2.03	0.20	0.20	0.20	-0.92	-0.65
	Downstream	MASED-09	0.20	-3.20	5.78	0.20	5.84	-4.07	5	1.41	200.00	0.20	-5.61	-2.91	-2.79	-2.96	-2.95	0.20	0.20	0.20	-1.41	-1.12
Gasambya	Upstream	GASED-13	0.20	-2.71	8.91	0.20	4.62	-3.83	5	1.43	200.00	0.20	-3.62	-2.91	-0.20	-2.49	-1.84	0.20	0.20	0.20	0.48	-0.43
	Downstream	GASED-14	0.20	-3.88	6.62	0.20	5.40	-4.54	5	2.57	200.00	0.20	0.20	-2.91	-0.51	-1.75	-3.77	0.20	0.20	0.20	-1.10	-2.18
Mahaza	Upstream	MAHSED-15	0.20	-2.02	4.33	0.20	5.34	-2.75	5	1.11	200.00	0.20	0.20	-2.91	1.21	-2.62	-2.55	0.20	0.20	0.20	-1.41	-0.65
	Downstream	MAHSED-19	0.20	-1.23	4.47	0.20	5.28	-2.00	5	1.21	200.00	0.20	0.20	-2.91	-1.25	-2.54	-2.28	0.20	0.20	0.20	-1.16	-0.70
Gisanze	Upstream	GSED-20	0.20	-2.28	4.49	0.20	6.61	-3.33	5	2.72	200.00	0.20	0.20	-2.91	-1.85	-0.09	-2.93	0.20	0.20	0.20	-0.99	-0.90
	Downstream	GSED-24	0.20	-1.90	4.95	0.20	6.56	-3.88	5	2.27	200.00	0.20	0.20	-2.91	-1.12	0.08	-2.87	0.20	0.20	0.20	-1.14	-0.33
Karambo	Upstream	KSED-25	0.20	-3.14	4.35	0.20	7.10	-3.41	5	1.05	200.00	0.20	0.20	-2.91	-0.93	-2.00	-3.69	0.20	0.20	0.20	-1.75	-1.53
	Downstream	KSED-26	5.78	-2.87	6.97	0.20	6.83	-2.26	5	3.36	200.00	0.20	-6.71	-2.91	-0.33	-0.02	-2.39	0.20	0.20	0.20	-1.15	-0.66

Mine	Stream Position	Analytes	Gd	Ge	Hf	Hg	Ho	In	Ir	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb	Nd	Ni	Os	P
		Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
		Crustal Abundance (Smith and Huyck)	**7**	**15**		**0.08**		**0.1**	**0.001**	**26000**		**30**	**0.9**	**21000**	**900**	**2**	**24000**	**20**	**25**	**80**		**1000**
		1. GAI ≥ 3: Significant enrichment (possible contamination)																				
		2. GAI ≥ 6: Extreme enrichment (likely contamination)																				
Nyanyumba	Upstream	NYASED-03	0.20	-3.01	NV	0.20	0.20	0.20	0.20	-3.32	0.40	-1.12	0.20	0.20	-3.88	5.00	200.00	-1.61	-6.29	5.00	0.20	-0.20
	Downstream	NYASED-02	0.20	-3.05	NV	0.20	0.20	0.20	0.20	-2.83	0.20	-0.56	0.20	-5.43	-1.81	5.00	200.00	-1.05	-6.02	5.00	0.20	-0.38
Masoro	Upstream	MASED-31	0.20	-2.65	NV	0.20	0.20	0.20	0.20	-2.67	0.20	-0.41	0.20	-6.10	-3.47	5.00	200.00	-0.32	0.20	-3.40	0.20	-0.34
	Downstream	MASED-09	0.20	-3.11	NV	0.20	0.20	0.20	0.20	-3.38	0.20	-1.54	0.20	-5.92	-3.75	5.00	200.00	-0.71	0.20	5.00	0.20	-0.28
Gasambya	Upstream	GASED-13	0.20	-3.38	NV	0.20	0.20	0.20	0.20	-3.34	0.84	-1.68	0.20	0.20	-4.87	5.00	200.00	-1.19	-5.54	5.00	0.20	-0.21
	Downstream	GASED-14	0.20	-3.59	NV	0.20	0.20	0.20	0.20	-4.62	0.20	-1.84	0.20	0.20	-4.15	5.00	200.00	-2.27	0.20	-3.03	0.20	-0.39
Mahaza	Upstream	MAHSED-15	0.20	-3.30	NV	0.20	0.20	0.20	0.20	-1.39	0.20	-0.51	0.20	-5.54	-2.73	5.00	-5.54	-0.43	0.20	-2.63	0.20	-0.24
	Downstream	MAHSED-19	0.20	-3.41	NV	0.20	0.20	0.20	0.20	-1.07	0.20	-0.36	0.20	-5.41	-2.25	5.00	-5.31	-0.12	0.20	-3.29	0.20	-0.13
Gisanze	Upstream	GSED-20	0.20	-3.82	NV	0.20	0.20	0.20	0.20	-1.77	0.20	-0.86	0.20	-5.57	-2.29	5.00	-5.68	-0.80	0.20	-3.31	0.20	-0.05
	Downstream	GSED-24	0.20	-3.29	NV	0.20	0.20	0.20	0.20	-0.69	0.20	0.72	0.20	-6.06	-3.69	5.00	-5.31	-0.37	0.20	-3.03	0.20	-0.26
Karambo	Upstream	KSED-25	0.20	-3.81	NV	0.20	0.20	0.20	0.20	-3.12	0.20	-0.53	0.20	-5.65	-3.34	5.00	-5.54	-1.74	0.20	5.00	0.20	-0.27
	Downstream	KSED-26	0.20	-3.07	NV	0.20	0.20	0.20	0.20	-2.40	0.20	0.45	0.20	-5.72	-3.48	5.00	-6.44	-2.14	-5.74	-3.19	0.20	-0.03

Mine	Stream Position	Analytes	Pb	Pd	Pr	Pt	Rb	Rh	Ru	Sb	Sc	Se	Si	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl
		Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
		Crustal Abundance (Smith and Huyck)	**16**	**0.01**		**0.005**	**120**					**0.09**	**270000**	**7**	**2.5**	**350**	**2**			**10**	**5000**	**1**
		1. GAI ≥ 3: Significant enrichment (possible contamination)																				
		2. GAI ≥ 6: Extreme enrichment (likely contamination)																				
Nyanyumba	Upstream	NYASED-03	0.10	0.20	0.20	0.20	-3.84	0.20	0.20	0.20	NV	4.23	-0.56	0.20	1.70	5.00	-1.27	0.20	0.20	-1.32	-1.52	0.20
	Downstream	NYASED-02	-0.02	0.20	0.20	0.20	-3.65	0.20	0.20	0.20	NV	5.49	-0.51	0.20	2.42	-5.49	-0.69	0.20	0.20	-1.92	-0.99	0.20
Masoro	Upstream	MASED-31	-0.03	0.20	0.20	0.20	-3.70	0.20	0.20	0.20	NV	5.51	-0.63	0.20	2.85	5.00	-0.47	0.20	0.20	-2.41	-0.34	0.20
	Downstream	MASED-09	-0.51	0.20	0.20	0.20	-4.91	0.20	0.20	0.20	NV	0.20	-0.54	0.20	2.20	5.00	-0.65	0.20	0.20	-1.93	-0.48	0.20
Gasambya	Upstream	GASED-13	1.85	0.20	0.20	0.20	-3.92	0.20	0.20	0.79	NV	0.20	-0.86	0.20	1.47	5.00	-1.28	0.20	0.20	-1.19	-1.56	0.20
	Downstream	GASED-14	-0.53	0.20	0.20	0.20	-4.39	0.20	0.20	0.20	NV	3.40	-0.66	0.20	1.07	5.00	0.91	0.20	0.20	-1.97	-1.93	0.20
Mahaza	Upstream	MAHSED-15	0.66	0.20	0.20	0.20	-3.17	0.20	0.20	0.20	NV	0.20	-0.89	0.20	1.77	5.00	1.09	0.20	0.20	-2.81	0.03	-1.03
	Downstream	MAHSED-19	0.60	0.20	0.20	0.20	-2.95	0.20	0.20	0.20	NV	0.20	-1.12	0.20	2.06	-5.63	1.15	0.20	0.20	-2.96	0.01	-0.74
Gisanze	Upstream	GSED-20	0.15	0.20	0.20	0.20	-1.95	0.20	0.20	0.20	NV	0.20	-0.87	0.20	3.55	5.00	1.68	0.20	0.20	-2.93	-0.44	-0.33
	Downstream	GSED-24	0.56	0.20	0.20	0.20	-1.93	0.20	0.20	0.20	NV	2.32	-1.16	0.20	4.05	5.00	1.47	0.20	0.20	-3.67	-0.02	0.01
Karambo	Upstream	KSED-25	0.74	0.20	0.20	0.20	-4.30	0.20	0.20	0.20	NV	0.20	-0.57	0.20	2.11	5.00	0.50	0.20	0.20	-2.41	-0.71	0.20
	Downstream	KSED-26	2.57	7.24	0.20	0.20	-2.72	0.20	0.20	0.20	NV	0.20	-0.81	0.20	3.22	-4.98	0.83	0.20	0.20	-2.05	-1.86	-1.28

Mine	Stream Position	Analytes	Tm	U	V	W	Y	Yb	Zn	Zr
		Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
		Crustal Abundance (Smith and Huyck)		**3**	**150**	**1**	**30**	**3**	**70**	**160**
		1. GAI ≥ 3: Significant enrichment (possible contamination)								
		2. GAI ≥ 6: Extreme enrichment (likely contamination)								
Nyanyumba	Upstream	NYASED-03	0.20	-1.18	-0.74	0.79	0.20	0.20	-2.59	-0.75
	Downstream	NYASED-02	0.20	-1.11	-1.73	0.74	0.20	0.20	-2.02	-0.75
Masoro	Upstream	MASED-31	0.20	-0.91	-1.19	0.93	0.20	0.20	-1.51	-0.46
	Downstream	MASED-09	0.20	-0.89	-2.14	0.45	0.20	0.20	-1.88	-0.14
Gasambya	Upstream	GASED-13	0.20	-0.24	-0.08	0.69	0.20	0.20	-1.93	-0.93
	Downstream	GASED-14	0.20	-1.72	-1.49	-0.60	0.20	0.20	-4.14	-1.62
Mahaza	Upstream	MAHSED-15	0.20	-0.45	-1.13	2.14	0.20	0.20	-1.69	0.01
	Downstream	MAHSED-19	0.20	-0.39	-0.99	3.06	0.20	0.20	-1.27	-0.04
Gisanze	Upstream	GSED-20	0.20	-0.85	-1.79	2.29	0.20	0.20	-1.70	-1.02
	Downstream	GSED-24	0.20	-0.77	-0.82	1.71	0.20	0.20	-1.88	-0.18
Karambo	Upstream	KSED-25	0.20	-1.30	-2.24	1.50	0.20	0.20	-2.42	-1.12
	Downstream	KSED-26	0.20	-0.86	-2.00	2.67	0.20	0.20	-1.51	-2.14

Note: Values in grey text show below detection limit concentrations and no GAI value was calculated whereas NV implies no value calculated due to absence of an average crustal abundance.

5.0 Legacy Tailings Results and Interpretations

5.1 Mineralogy

Table 5-1 shows the XRD results of the Rutongo mines legacy tailings lithologies.

Nyanyumba mine:

The primary lithologies that are diagnostic of the Nyanyumba mine include Quartz Vein and Quartzite.

The Nyanyumba Quartz vein consists entirely of Quartz whereas the Quartzite is dominated by Quartz with major proportions of Muscovite.

Masoro mine:

The main lithologies that are diagnostic of the Masoro mine include Schist, Quartz vein and Quartzite.

The Masoro Schist is dominated by Muscovite with major proportions of Quartz and minor proportions of Kaolinite and Dravite. The Masoro Quartz vein consists entirely of Quartz whereas the Masoro Quartzite is dominated by Quartz with minor proportions of Kaolinite and trace proportions of Muscovite.

Gasambya mine:

The main lithologies that are diagnostic of this mine include Schist, Quartz vein and Quartzite.

The Gasambya Schist is dominated by Muscovite with major proportions of Quartz and minor proportions of Palygorskite and Kaolinite. The Gasambya Quartzite consists of mainly Quartz with minor proportions of Dravite and trace proportions of Muscovite. Lastly, the Gasambya Quartz vein consists entirely of Quartz.

Mahaza mine:

The primary lithologies that are diagnostic of this mine include Quartz vein, Quartzite and Phyllite.

The Mahaza Quartz vein contains only Quartz whereas the Quartzite is dominated by Quartz with major proportions of Kaolinite and minor proportions of Muscovite and Goethite. The Mahaza Phyllite is dominated by Muscovite with major proportions of Quartz and minor proportions of Kaolinite and Hematite respectively.

Gisanze mine:

The main lithologies that characterise this mine include Quartzite, Phyllite and Quartz vein.

The Gisanze Quartzite is dominated Quartz with major proportions of Muscovite and minor proportions of Kaolinite and Palygorskite as well as trace proportions of Dravite. The Phyllite is dominated by Muscovite with major proportions of Quartz and minor proportions of Palygorskite and Dravite. Lastly, the Gisanze Quartz vein comprises entirely of Quartz.

Karambo mine:

The primary lithologies that are diagnostic of the Karambo mine include Fe rich Quartz Vein, Quartz vein, Phyllite and Quartzite.

The Karambo Fe rich Quartz vein is dominated by Goethite and Quartz whereas the Quartz vein consists entirely of Quartz. The Karambo Phyllite is dominated by Muscovite with minor proportions of Quartz and Kaolinite. Lastly, the Karambo Quartzite is dominated by Quartz with minor proportions of Kaolinite and Muscovite.

The XRD analyses did not detect the presence of acid producing minerals (like sulphides) in any of the Rutongo mines legacy tailings lithologies. This suggests that the various tailings lithologies are likely to be non-potential acid generating with a minimal to low acid rock drainage (ARD) risk.

Table 5-1: Rutongo Mines Legacy Tailings XRD Results

Mineral	Formula	Mine																	
		Nyanyumba		Masoro			Gasambya			Mahaza			Gisanze			Karambo			
		Sample ID																	
		NYA-SN-01 &03	NYA-SN-02&04	MAS-BV-05	MAS-BV-06	MAS-BV-07	GA-TS-10	GA-TS-11	GA-TS-12	MAH-TS-16	MAH-TS-17	MAH-TS-18	GS-TS-21	GS-TS-22	GS-TS-23	KE-LT-27	KE-LT-28	KE-LT-29	KE-LT-30
		Rock type																	
		Quartz Vein	Quartzite	Schist	Quartz Vein	Quartzite	Schist	Quartzite	Quartz Vein	Quartz Vein	Quartzite	Phyllite	Quartzite	Phyllite	Quartz Vein	Fe rich Quartz Vein	Quartz Vein	Phyllite	Quartzite
		Composition (%)																	
Quartz	SiO_2	100	83.21	34.26	100	96.98	29.05	98.08	100	100	80.99	19.22	71.93	28.92	100	35.3	100	7.11	96.14
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	-	16.79	57.74	-	0.23	63.17	0.89	-	-	4.88	66.04	23.56	67.77	-	-	-	82.95	1.72
Kaolinite	$Al_2Si_2O_5(OH)_4$	-	-	6.98	-	2.78	3.79	-	-	-	10.42	7.67	1.09	-	-	-	-	9.94	2.14
Goethite	$Fe_2O_3.H_2O$	-	-	-	-	-	-	-	-	-	3.71	-	-	-	-	64.7	-	-	-
Palygorskite	$Mg_5Si_8O_{20}(OH)_2 \cdot 8H_2O$	-	-	-	-	-	3.99	-	-	-	-	-	2.81	1.71	-	-	-	-	-
Dravite	$NaMg_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$	-	-	1.01	-	-	-	1.03	-	-	-	-	0.62	1.6	-	-	-	-	-
Hematite	Fe_2O_3	-	-	-	-	-	-	-	-	-	-	7.07	-	-	-	-	-	-	-

5.2 Acid Base Accounting

Sulphur speciation and Acid Base Accounting analysis were undertaken on the Rutongo mines legacy tailings materials. The results are presented in Table 5-2 and Table 5-3 respectively.

The sulfur speciation results reported for the Rutongo mines legacy tailings lithologies show minor to negligible total sulfur percentages which consists of both sulfate and sulfide S proportions. Overall, the sulfide S percentages of the legacy tailings lithologies reported < 0.30% and therefore, are considered non-potential acid generating materials, which suggests they have a minimal to low risk for ARD.

Table 5-2: Rutongo Mines Legacy Tailings Sulfur Speciation Results

Mine	Rock Type	Sample ID	Total Sulfur	Sulfide S	Sulfate Sulfur
			%	%	%
Nyanyumba	Quartz Vein	NYA-SN-01 &03	0.011	<0.010	<0.010
	Quartzite	NYA-SN-02&04	0.014	<0.010	<0.010
Masoro	Schist	MAS-BV-05	0.010	0.010	<0.010
	Quartz Vein	MAS-BV-06	0.118	<0.010	0.112
	Quartzite	MAS-BV-07	<0.010	<0.010	<0.010
Gasambya	Schist	GA-TS-10	0.010	<0.010	<0.010
	Quartzite	GA-TS-11	0.057	0.041	0.016
	Quartz Vein	GA-TS-12	0.021	0.013	<0.010
Mahaza	Quartz Vein	MAH-TS-16	<0.010	<0.010	<0.010
	Quartzite	MAH-TS-17	0.071	0.011	0.060
	Phyllite	MAH-TS-18	0.068	<0.010	0.059
Gisanze	Quartzite	GS-TS-21	<0.010	<0.010	<0.010
	Phyllite	GS-TS-22	<0.010	<0.010	<0.010
	Quartz Vein	GS-TS-23	0.047	0.024	0.023
Karambo	Fe rich Quartz Vein	KE-LT-27	0.012	<0.010	<0.010
	Quartz Vein	KE-LT-28	0.012	<0.010	<0.010
	Phyllite	KE-LT-29	0.010	<0.010	<0.010
	Quartzite	KE-LT-30	0.010	<0.010	<0.010

The ABA analyses resulted in the following classifications for the legacy tailings lithologies obtained from the respective Rutongo mines:

Potential acid generating (PAG) lithologies:

- Nyanyumba Quartz vein and Quartzite
- Masoro Quartz vein
- Gasambya Quartzite and Quartz vein
- Mahaza Quartzite, Quartz vein and Phyllite
- Gisanze Quartz vein and Quartzite
- Karambo Fe rich Quartz vein and Quartz vein

These lithologies are suggested to be PAG because they reported moderately acidic to alkaline paste pH values (6 to 8.3) with neutralization potential ratios (NPR) less than 1 (0.001 to 0.727) and net neutralization potential (NNP) values between -20 and 20 (-2.96 to -0.094).

Intermediate potential to generate acid lithologies:

- Masoro Schist and Quartzite
- Gasambya Schist
- Gisanze Phyllite
- Karambo Phyllite

These lithologies are suggested to have an intermediate potential to generate acid because they reported moderately acidic to slightly alkaline paste pH values (5.6 to 7.8) with NPR values which varies between 1 and 4 respectively and NNP values between -20 and 20 (-3.19 to 0.185).

Non potential acid generating (non-PAG) lithologies:

- Karambo Quartzite

This tailings lithology is suggested to be non-PAG because it reported moderately acidic paste pH value (6.8) with an NPR value between 1 and 4 respectively as well as NNP values between -20 and 20.

The ABA tests are based on determining the sulphur/sulphide content of a material to calculate the sulphide acid potential (AP) and neutralisation potential (NP), which is determined by the proportion of carbonate and other alkaline minerals. This evaluation determines whether materials will have a net acid-generating or neutralising potential. Consequently, ABA tests do not directly measure acid production over time but estimate the potential for acid generation based on the mineralogical composition of a material.

On average, the NP values for the Rutongo mines legacy tailings lithologies are less than their AP values. However, this is not due to an abundance of acid generating minerals (Sulfides) but rather a lack of rapidly dissolving neutralising minerals like carbonates being present in the materials.

Due to the contradictions between complex in-field and laboratory test conditions when determining the acid generation potential of mine waste materials, geochemists often use phase diagrams where sample data is plotted on Paste pH vs NPR charts. This is used to graphically classify otherwise conflicting results that could potentially occur. Refer to Figure 5-1 below for the acid generating potential plot for the Rutongo mines legacy tailings lithologies.

Table 5-3: Rutongo Mines Legacy Tailings ABA Results

Mine	Rock Type	Sample ID	Paste pH	Total S	Sulphide Acid Potential (AP)	Neutralization Potential (NP)	Neutralisation potential ratio (NPR)	Nett Neutralization Potential (NNP)	Classification
			-	%	kg/t $CaCO_3$	kg/t $CaCO_3$		Kg/t $CaCO_3$	
		Non-PAG	>5.5	<0.3			>4	>20	
		Intermediate	3.5-5.5				1 to 4	-20 to 20	
		PAG/AG	<3.5	>0.3			<1	<-20	
Nyanyumba	Quartz Vein	NYA-SN-01 &03	6.6	0.011	0.344	0.250	0.727	-0.094	PAG
	Quartzite	NYA-SN-02&04	7.8	0.014	0.438	0.002	0.006	-0.435	PAG
Masoro	Schist	MAS-BV-05	5.6	0.010	0.313	-1.48	4.74	-1.80	Intermediate
	Quartz Vein	MAS-BV-06	6.2	0.118	3.69	0.497	0.135	-3.19	PAG
	Quartzite	MAS-BV-07	6.5	<0.010	0.313	-0.493	1.58	-0.81	Intermediate
Gasambya	Schist	GA-TS-10	7.8	0.010	0.313	-0.493	1.58	-0.81	Intermediate
	Quartzite	GA-TS-11	7.2	0.057	1.78	-0.245	0.14	-2.03	PAG
	Quartz Vein	GA-TS-12	7.5	0.021	0.656	-0.245	0.373	-0.901	PAG
Mahaza	Quartz Vein	MAH-TS-16	6.7	<0.010	0.313	0.002	0.008	-0.310	PAG
	Quartzite	MAH-TS-17	6.3	0.071	2.22	-0.740	0.334	-2.96	PAG
	Phyllite	MAH-TS-18	7.2	0.068	2.13	0.002	0.001	-2.12	PAG
Gisanze	Quartzite	GS-TS-21	8.3	<0.010	0.313	0.002	0.008	-0.310	PAG
	Phyllite	GS-TS-22	7.6	<0.010	0.313	-0.493	1.58	-0.805	Intermediate
	Quartz Vein	GS-TS-23	6.2	0.047	1.47	-0.740	0.504	-2.21	PAG
Karambo	Fe rich Quartz Vein	KE-LT-27	6.0	0.012	0.375	0.250	0.667	-0.125	PAG
	Quartz Vein	KE-LT-28	6.9	0.012	0.375	0.002	0.007	-0.373	PAG
	Phyllite	KE-LT-29	7.0	0.010	0.313	0.497	1.59	0.185	Intermediate
	Quartzite	KE-LT-30	6.8	0.010	0.313	0.745	2.38	0.432	Non-PAG

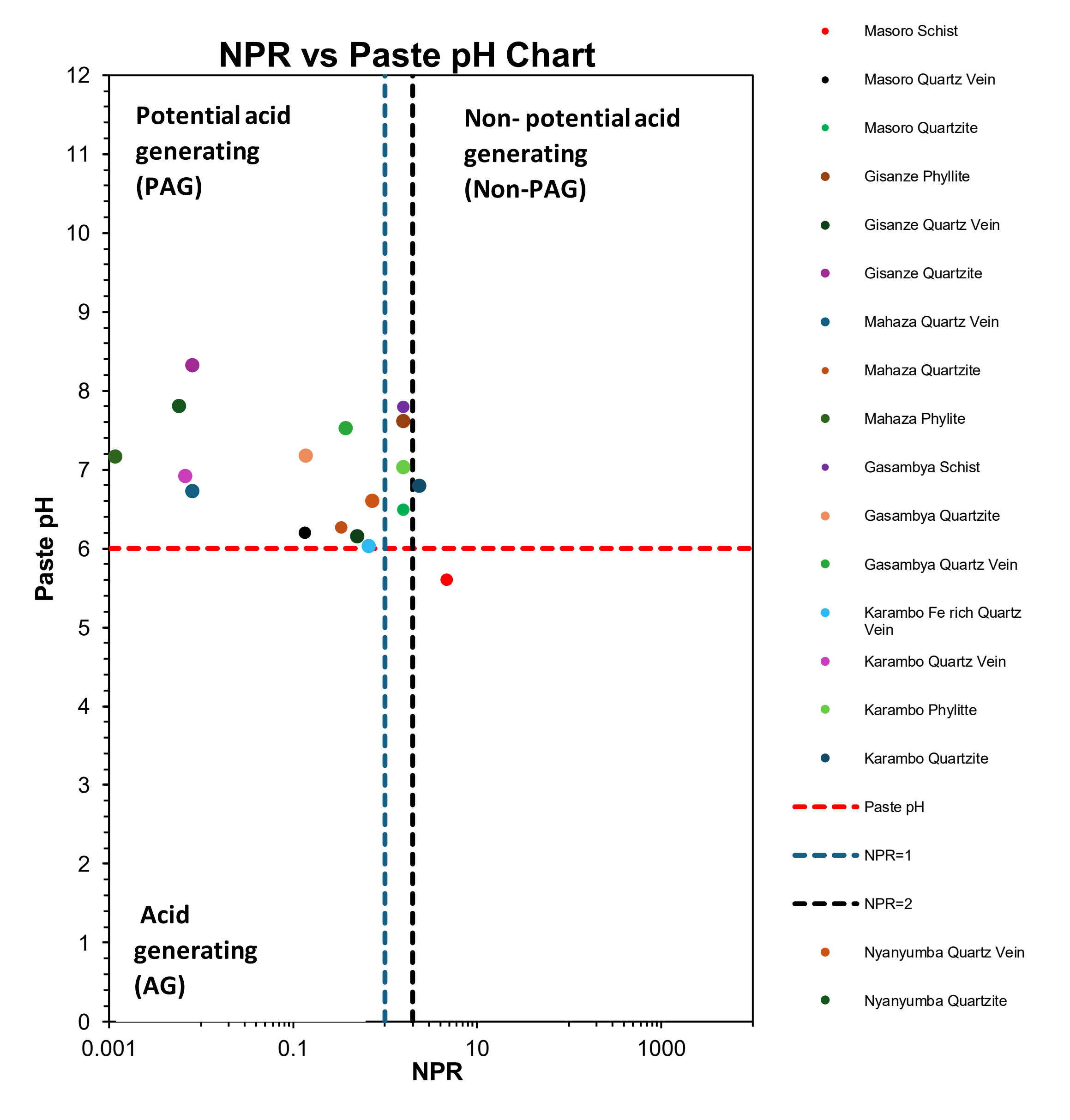

Figure 5-1: Rutongo Mines Legacy Tailings Materials Acid Generating Potential Plot

5.3 Synthetic Precipitation Leaching Procedure Screening

The Synthetic Precipitation Leaching Procedure (SPLP) results are provided in Table 5-4. Based on the results, the following analytes exceeded applicable local and international water quality and effluent standard limits and could potentially be COPCs.

Referring to the screening tables below, the following exceedances were reported:

Nyanyumba Quartz vein:

- Mn (WHO Drinking and RS Irrigation)

Nyanyumba Quartzite:

- Mn (WHO Drinking)

Masoro Schist:

- pH (IFC and RS Livestock)

Masoro Quartz vein:

- Mn (WHO Drinking and RS Irrigation)
- pH (IFC and RS Livestock)

Masoro Quartzite:

- Mn (WHO Drinking)

Gasambya Quartzite:

- Mn (WHO Drinking and RS Irrigation)
- pH (IFC and RS Livestock)

Gasambya Quartz vein:

- As (WHO Drinking)
- Fe (RS Livestock)
- Mn (WHO Drinking, RS Irrigation and Livestock)

Mahaza Quartz vein:

- Mn (WHO Drinking, RS Irrigation)

Mahaza Quartzite:

- pH (IFC and RS Livestock)

Gisanze Quartz vein:

- Mn (WHO Drinking, RS Irrigation and Livestock)
- pH (IFC and RS Livestock)

Gisanze Phylitte:

- pH (IFC and RS Livestock)

Karambo Fe rich Quartz vein:

- As and Mn (WHO Drinking)
- pH (IFC and RS Livestock)

Karambo Quartz vein:

- Mn (WHO Drinking, RS Irrigation and Livestock)

Karambo Quartzite:

Mn (WHO Drinking)

- pH (IFC and RS Livestock)

Table 5-4: Rutongo Mines Legacy Tailings Materials SPLP Screening Results

Mine	Rock Type	Analytes	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr (total)	Cr(VI)	Cs	Cu	Dy	Er	Eu	Fe	Ga
		Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
		1. WHO: Drinking Water (2022)			**0.01**		**2.4**	**1.3**				**0.003**			**0.05**		**2**						
		2. WHO: Recreational Use (2021)		**18**	**0.2**										**1**		**40**						
		3. IFC: Mining Effluent			**0.1**							**0.05**						**0.3**				**2**	
		4. RS 109 of 2009: Effluent Standards				**0.01**												**3**				**3.5**	
		5. RS 188 (2013): Irrigation Use			**5**	**0.1**			**0.1**			**0.01**		**0.05**	**0.1**			**0.2**				**5**	
		6. RS 190 (2013): Livestock Watering			**5**	**2**					**200**	**0.5**		**1**	**1**			**0.5**				**0.3**	
Nyanyumba	Quartz Vein	NYA-SN-01 &03	0.015	0.050	0.0005	0.0005	0.013	0.013	0.013	0.0005	1.09	0.0005	0.0005	0.013	0.013	0.005	0.018	0.005	0.005	0.005	0.005	0.14	0.0005
	Quartzite	NYA-SN-02&04	0.005	0.050	0.0005	0.0005	0.013	0.013	0.013	0.0005	0.50	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.137	0.0005
Masoro	Schist	MAS-BV-05	0.0005	0.050	0.009	0.0005	0.013	0.013	0.013	0.0005	1.57	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.013	0.0005
	Quartz Vein	MAS-BV-06	0.0005	0.050	0.002	0.0005	0.013	0.013	0.013	0.0005	0.50	0.0005	0.0005	0.013	0.013	0.005	0.021	0.005	0.005	0.005	0.005	0.11	0.0005
	Quartzite	MAS-BV-07	0.0005	0.050	0.003	0.0005	0.013	0.013	0.013	0.0005	0.984	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.171	0.0005
Gasambya	Schist	GA-TS-10	0.019	0.050	0.002	0.0005	0.013	0.013	0.013	0.0005	1.01	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.013	0.0005
	Quartzite	GA-TS-11	0.005	0.050	0.0005	0.0005	0.013	0.013	0.013	0.0005	1.34	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.261	0.0005
	Quartz Vein	GA-TS-12	0.002	0.050	0.025	0.0005	0.013	0.013	0.013	0.0005	1.06	0.0005	0.0005	0.013	0.013	0.005	0.003	0.005	0.005	0.005	0.005	0.367	0.0005
Mahaza	Quartz Vein	MAH-TS-16	0.0005	0.050	0.001	0.0005	0.013	0.013	0.013	0.0005	0.50	0.0005	0.002	0.013	0.013	0.005	0.010	0.005	0.005	0.005	0.005	0.157	0.0005
	Quartzite	MAH-TS-17	0.0005	0.050	0.0005	0.0005	0.013	0.013	0.013	0.0005	0.50	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.013	0.0005
	Phyllite	MAH-TS-18	0.0005	0.050	0.0005	0.0005	0.013	0.013	0.013	0.0005	1.32	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.013	0.0005
Gisanze	Quartzite	GS-TS-21	0.0005	0.21	0.002	0.0005	0.013	0.013	0.013	0.001	1.10	0.0005	0.001	0.013	0.013	0.005	0.001	0.005	0.005	0.005	0.005	0.1	0.0005
	Phyllite	GS-TS-22	0.0005	0.050	0.004	0.0005	0.013	0.013	0.013	0.0005	0.50	0.0005	0.002	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.1	0.0005
	Quartz Vein	GS-TS-23	0.0005	0.050	0.0005	0.0005	0.013	0.013	0.013	0.0005	0.50	0.0005	0.0005	0.013	0.013	0.005	0.006	0.005	0.005	0.005	0.005	0.16	0.0005
Karambo	Fe rich Quartz Vein	KE-LT-27	0.0005	0.050	0.011	0.0005	0.013	0.013	0.013	0.0005	0.50	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.036	0.0005
	Quartz Vein	KE-LT-28	0.018	0.050	0.0005	0.0005	0.013	0.013	0.013	0.0005	1.10	0.0005	0.0005	0.013	0.013	0.005	0.008	0.005	0.005	0.005	0.005	0.201	0.0005
	Phyllite	KE-LT-29	0.005	0.050	0.002	0.0005	0.013	0.013	0.013	0.0005	1.023	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.013	0.0005
	Quartzite	KE-LT-30	0.002	0.050	0.006	0.0005	0.013	0.013	0.013	0.0005	1.089	0.0005	0.0005	0.013	0.013	0.005	0.0005	0.005	0.005	0.005	0.005	0.048	0.0005

Mine	Rock Type	Analytes	Gd	Ge	Hf	Hg	Ho	In	Ir	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb	Nd	Ni	Os	P
		Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
		1. WHO: Drinking Water (2022)				**0.006**									**0.08**		**50**			**0.07**		
		2. WHO: Recreational Use (2021)													**8**					**1.4**		
		3. IFC: Mining Effluent				**0.002**														**0.5**		
		4. RS 109 of 2009: Effluent Standards				**0.002**														**3**		
		5. RS 188 (2013): Irrigation Use										**2.5**			**0.2**	**0.01**	**3**			**0.2**		
		6. RS 190 (2013): Livestock Watering				**0.05**				**20**				**80**	**0.5**		**100**			**1**		**1**
Nyanyumba	Quartz Vein	NYA-SN-01 &03	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.004	0.0005	0.500	0.478	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.0005
	Quartzite	NYA-SN-02&04	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.9	0.0005	0.005	0.0005	0.500	0.17	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.019
Masoro	Schist	MAS-BV-05	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	1.667	0.0005	0.001	0.0005	0.500	0.013	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.308
	Quartz Vein	MAS-BV-06	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.009	0.0005	0.500	0.431	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.016
	Quartzite	MAS-BV-07	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.0005	0.0005	0.500	0.190	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.102
Gasambya	Schist	GA-TS-10	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	1.853	0.0005	0.0005	0.0005	0.500	0.013	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.0005
	Quartzite	GA-TS-11	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.002	0.0005	0.500	0.433	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.0005
	Quartz Vein	GA-TS-12	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.003	0.0005	0.500	0.577	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.018
Mahaza	Quartz Vein	MAH-TS-16	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.010	0.0005	0.500	0.409	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.006
	Quartzite	MAH-TS-17	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.0005	0.0005	0.500	0.066	0.013	0.500	0.0005	0.001	0.013	0.0005	0.0005
	Phyllite	MAH-TS-18	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	1.631	0.0005	0.0005	0.0005	0.500	0.013	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.080
Gisanze	Quartzite	GS-TS-21	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	3.558	0.0005	0.002	0.0005	0.500	0.013	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.0005
	Phyllite	GS-TS-22	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	1.09	0.0005	0.0005	0.0005	0.500	0.03	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.055
	Quartz Vein	GS-TS-23	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.0005	0.0005	0.500	0.51	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.0005
Karambo	Fe rich Quartz Vein	KE-LT-27	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.0005	0.0005	0.500	0.11	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.055
	Quartz Vein	KE-LT-28	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.250	0.0005	0.011	0.0005	0.500	0.672	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.044
	Phyllite	KE-LT-29	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	2.260	0.0005	0.0005	0.0005	0.500	0.013	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.006
	Quartzite	KE-LT-30	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.621	0.0005	0.001	0.0005	0.500	0.149	0.013	0.500	0.0005	0.0005	0.013	0.0005	0.057

Mine	Rock Type	Analytes	Pb	Pd	Pr	Pt	Rb	Rh	Ru	Sb	Sc	Se	Si	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl
		Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
		1. WHO: Drinking Water (2022)	**0.01**							**0.02**		**0.04**										
		2. WHO: Recreational Use (2021)																				
		3. IFC: Mining Effluent	**0.2**																			
		4. RS 109 of 2009: Effluent Standards	**0.1**									**0.02**										
		5. RS 188 (2013): Irrigation Use	**5**									**0.02**										
		6. RS 190 (2013): Livestock Watering	**0.05**									**0.5**										
Nyanyumba	Quartz Vein	NYA-SN-01 &03	0.0005	0.001	0.0005	0.0005	0.002	0.0005	0.0005	0.0005	0.0005	0.002	0.26	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Quartzite	NYA-SN-02&04	0.0005	0.0005	0.0005	0.0005	0.007	0.0005	0.0005	0.0005	0.0005	0.0005	0.34	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Masoro	Schist	MAS-BV-05	0.0005	0.0005	0.0005	0.0005	0.008	0.0005	0.0005	0.0005	0.0005	0.0005	0.71	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Quartz Vein	MAS-BV-06	0.0005	0.0005	0.0005	0.0005	0.003	0.0005	0.0005	0.0005	0.0005	0.0005	0.26	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Quartzite	MAS-BV-07	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.46	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Gasambya	Schist	GA-TS-10	0.0005	0.001	0.0005	0.0005	0.008	0.0005	0.0005	0.0005	0.0005	0.008	0.68	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Quartzite	GA-TS-11	0.0005	0.0005	0.0005	0.0005	0.003	0.0005	0.0005	0.0005	0.0005	0.0005	0.27	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Quartz Vein	GA-TS-12	0.0005	0.0005	0.0005	0.0005	0.002	0.0005	0.0005	0.0005	0.0005	0.008	0.41	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Mahaza	Quartz Vein	MAH-TS-16	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.39	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.003	0.0005
	Quartzite	MAH-TS-17	0.0005	0.0005	0.0005	0.0005	0.002	0.0005	0.0005	0.0005	0.0005	0.0005	0.75	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Phyllite	MAH-TS-18	0.0005	0.0005	0.0005	0.0005	0.005	0.0005	0.0005	0.0005	0.0005	0.0005	0.99	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Gisanze	Quartzite	GS-TS-21	0.0005	0.0005	0.0005	0.0005	0.017	0.0005	0.0005	0.0005	0.0005	0.0005	1.44	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.007	0.0005
	Phyllite	GS-TS-22	0.001	0.0005	0.0005	0.0005	0.006	0.0005	0.0005	0.0005	0.0005	0.0005	0.37	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.029	0.0005
	Quartz Vein	GS-TS-23	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.24	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Karambo	Fe rich Quartz Vein	KE-LT-27	0.0005	0.0005	0.0005	0.0005	0.003	0.0005	0.0005	0.0005	0.0005	0.0005	0.22	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Quartz Vein	KE-LT-28	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.007	0.33	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Phyllite	KE-LT-29	0.0005	0.0005	0.0005	0.0005	0.004	0.0005	0.0005	0.0005	0.0005	0.0005	1.49	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Quartzite	KE-LT-30	0.0005	0.0005	0.0005	0.0005	0.003	0.0005	0.0005	0.0005	0.0005	0.005	0.41	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005

Mine	Rock Type	Analytes	Tm	U	V	W	Y	Yb	Zn	Zr	pH	EC	TDS	Tot Alk	Cl	SO4	NO3	NO2	F	Free NH3	Ortho-P	Total Cn
		Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*		*mS/m*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
		1. WHO: Drinking Water (2022)		**0.03**													**50**	**3**	**1.5**			
		2. WHO: Recreational Use (2021)																				
		3. IFC: Mining Effluent							**0.5**		**6-9**											**1**
		4. RS 109 of 2009: Effluent Standards							**5**		**5-9**		**2000**									
		5. RS 188 (2013): Irrigation Use			**0.1**				**2**				**450**				**5**		**1**			
		6. RS 190 (2013): Livestock Watering		**0.2**	**0.1**				**25**		**6-9**		**1000**	**500**	**100**	**250**	**25**	**10**				
Nyanyumba	Quartz Vein	NYA-SN-01 &03	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.00	1.90	5	10	2	1	0.05	0.025	0.1	0.05	0.05	0.035
	Quartzite	NYA-SN-02&04	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.20	1.40	20	20	1	1	0.05	0.025	0.1	0.05	0.05	0.035
Masoro	Schist	MAS-BV-05	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	5.80	1.50	5	20	1	1	0.05	0.025	0.1	0.1	0.05	0.035
	Quartz Vein	MAS-BV-06	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	5.90	1.80	5	30	2	1	0.05	0.025	0.1	0.1	0.05	0.035
	Quartzite	MAS-BV-07	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.20	1.30	5	10	1	1	0.05	0.025	0.7	0.1	0.05	0.035
Gasambya	Schist	GA-TS-10	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.10	1.50	5	30	1	1	0.05	0.025	0.1	0.2	0.05	0.035
	Quartzite	GA-TS-11	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	5.80	1.30	5	30	1	1	0.05	0.025	0.1	0.2	0.05	0.035
	Quartz Vein	GA-TS-12	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.30	1.40	5	20	1	1	0.05	0.025	0.1	0.05	0.05	0.035
Mahaza	Quartz Vein	MAH-TS-16	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.30	1.80	22	30	3	1	0.05	0.025	0.1	0.05	0.05	0.035
	Quartzite	MAH-TS-17	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	5.60	1.30	14	20	1	1	0.05	0.025	0.1	0.200	0.05	0.035
	Phyllite	MAH-TS-18	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.00	1.50	14	20	1	1	0.05	0.025	0.1	0.200	0.05	0.035
Gisanze	Quartzite	GS-TS-21	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	7.20	2.20	38	10	1	1	0.05	0.025	0.1	0.300	0.05	0.035
	Phyllite	GS-TS-22	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	5.50	1.80	32	20	1	1	0.4	0.025	0.1	0.200	0.05	0.035
	Quartz Vein	GS-TS-23	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	5.90	1.60	24	20	2	1	0.05	0.025	0.1	0.200	0.05	0.035
Karambo	Fe rich Quartz Vein	KE-LT-27	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	5.50	1.40	24	10	1	1	0.05	0.025	0.1	0.2	0.05	0.035
	Quartz Vein	KE-LT-28	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.30	1.400	32	20	1	1	0.05	0.025	0.1	0.05	0.05	0.035
	Phyllite	KE-LT-29	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	6.40	2.100	24	20	1	1	0.05	0.025	0.8	0.05	0.05	0.035
	Quartzite	KE-LT-30	0.0005	0.0005	0.013	0.0005	0.0005	0.0005	0.013	0.0005	5.90	1.300	20	20	1	1	0.05	0.025	0.1	0.05	0.05	0.035

Note: Values in grey text represent below detection limit concentrations

5.4 Geochemical Source Terms

To assess or predict impacts to surface and groundwater resources from any material or waste facility that may be a significant source of contamination, a source term should be derived. Preliminary source terms have been modelled for the Rutongo mines legacy tailings lithologies.

To simulate the conditions that the legacy tailings piles will be subject to, the model was developed by allowing a freely available supply of oxygen to the tailings piles, thereby representing unlimited contact between the Earth's atmosphere and the lithologies in the tailings piles.

Evaporation was not modelled due to PHREEQC's limitations in concentrating mixtures over time steps. The source term results are summarised in Table 5-5. Half detection limits were used for those common major and trace elements that reported below detection limits.

Based on the modelled source terms, the following exceedances are noted for the various legacy tailings materials for each mine:

Nyanyumba

Quartz vein:

- Mn (WHO Drinking and RS Irrigation)

Quartzite:

- Mn (WHO Drinking)

Masoro

Quartz vein:

- Mn (WHO Drinking, RS Irrigation and Livestock)

Quartzite:

- Mn (WHO Drinking)

Gasambya

Quartzite:

- Mn (WHO Drinking and RS Irrigation)

Quartz vein:

- As (WHO Drinking)
- Fe (RS Livestock)
- Mn (WHO Drinking, RS Irrigation and Livestock)

Mahaza

Quartz vein:

- Mn (WHO Drinking, RS Irrigation)

Gisanze

Quartz vein:

- Mn (WHO Drinking, RS Irrigation and Livestock)

Karambo

Fe rich Quartz vein:

- As and Mn (WHO Drinking)
- pH (IFC and RS Livestock)

Quartz vein:

- Mn (WHO Drinking, RS Irrigation and Livestock)

Quartzite:

- Mn (WHO Drinking)

Table 5-5: Rutongo Mines Legacy Tailings Materials Source Term Screening Results

Element	Units	WHO: Drinking Water (2022)	WHO: Recreational Use (2021)	IFC: Mining Effluent	RS 109 (2009): Effluent Standards	RS 188 (2013): Irrigation Use	RS 190 (2013): Livestock Watering	Nyanyumba Quartz Vein	Nyanyumba Quartzite	Masoro Schist	Masoro Quartz vein	Masoro Quartzite	Gasambya Schist	Gasambya Quartzite	Gasambya Quartz vein	Mahaza Quartz vein	Mahaza Quartzite	Mahaza Phyllite	Gisanze Quartzite	Gisanze Phyllite	Gisanze Quartz vein	Karambo Fe rich Quartz vein	Karambo Quartzite	Karambo Phyllite	Karambo Quartz vein
Ag	mg/L							0.015	0.005	0.000	0.000	0.000	0.019	0.005	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.017
Al	mg/L		18					0.025	0.000	0.000	0.000	0.000	0.004	0.000	0.025	0.000	0.000	0.000	0.005	0.004	0.025	0.023	0.000	0.000	0.023
As	mg/L	0.01	0.2	0.1		5	5	0.000	0.000	0.009	0.002	0.003	0.002	0.000	0.025	0.001	0.000	0.000	0.002	0.004	0.000	0.010	0.006	0.002	0.000
Au	mg/L				0.01	0.1	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	mg/L	2.4						0.006	0.007	0.000	0.007	0.007	0.007	0.000	0.007	0.007	0.007	0.007	0.000	0.000	0.007	0.006	0.007	0.007	0.006
Ba	mg/L	1.3						0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.007	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Be	mg/L					0.1		0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.007	0.007	0.006
HCO3	mg/L							7.58	16.85	20.80	21.91	11.84	37.44	23.54	17.40	26.29	38.19	39.21	37.50	25.32	14.17	6.08	20.99	21.72	16.74
Ca	mg/L						200	1.09	0.250	1.57	1.00	0.984	1.01	1.34	1.06	1.00	0.250	1.32	1.10	1.10	0.500	1.03	1.09	1.023	1.03
Cd	mg/L	0.003		0.05		0.01	0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ce	mg/L							0.002	0.000	0.000	0.002	0.000	0.004	0.000	0.000	0.002	0.000	0.000	0.001	0.002	0.000	0.000	0.001	0.002	0.000
Cl	mg/L						100	2.00	0.500	0.500	2.00	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	2.00	1.88	0.500	0.500	1.877
Co	mg/L					0.05	1	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Cr	mg/L	0.05	1			0.1	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cs	mg/L	2	40					0.018	0.003	0.003	0.021	0.003	0.003	0.003	0.003	0.010	0.003	0.003	0.001	0.001	0.006	0.008	0.001	0.001	0.008
Cu	mg/L			0.3	3	0.2	0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dy	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Er	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Eu	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F	mg/L	1.5				1		0.050	0.050	0.050	0.050	0.700	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.047	0.050	0.800	0.047
Fe	mg/L			2	3.5	5	0.3	0.140	0.137	0.007	0.110	0.171	0.007	0.261	0.367	0.157	0.000	0.000	0.100	0.100	0.160	0.000	0.048	0.100	0.000
Ga	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gd	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
He	mg/L							1.23	1.23	1.23	1.23	1.24	1.24	1.23	1.23	1.23	1.23	1.23	1.24	1.24	1.23	1.23	1.23	1.23	1.23
Hf	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hg	mg/L	0.006		0.002	0.002		0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ho	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
In	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	mg/L						20	0.125	0.888	9.80	0.125	4.65	0.225	3.72	0.125	0.125	14.63	12.57	0.160	0.215	0.125	0.12	9.19	7.12	0.12
La	mg/L							0.001	0.000	0.002	0.001	0.000	0.002	0.002	0.001	0.001	0.002	0.002	0.002	0.002	0.001	0.000	0.002	0.002	0.000
Li	mg/L					2.5		0.004	0.005	0.001	0.009	0.002	0.030	0.002	0.003	0.010	0.003	0.003	0.002	0.002	0.003	0.010	0.001	0.002	0.010
Lu	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	mg/L						80	0.250	0.250	0.235	0.250	0.250	6.26	0.235	0.250	0.250	0.250	0.250	3.16	5.68	0.250	0.235	0.250	0.250	0.235
Mn	mg/L	0.08	8			0.2	0.5	0.478	0.170	0.006	0.431	0.190	0.013	0.433	0.577	0.409	0.066	0.006	0.006	0.030	0.510	0.103	0.149	0.006	0.631
Mo	mg/L					0.01		0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.007	0.007	0.006
NO3	mg/L	50				5	25	0.406	0.133	0.406	0.406	0.406	0.770	0.770	0.133	0.133	0.770	0.770	1.13	1.15	0.770	0.72	1.13	1.145	0.72
Na	mg/L	50				3	100	0.250	0.250	0.245	0.250	0.250	0.250	0.245	0.250	0.250	0.250	0.250	0.245	0.245	0.250	0.235	0.250	0.250	0.235
Nd	mg/L							0.000	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	mg/L	0.07	1.4	0.5	3	0.2	1	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.007	0.007	0.006
P	mg/L							0.016	0.019	0.308	0.016	0.102	0.058	0.000	0.018	0.006	0.000	0.080	0.000	0.055	0.018	0.052	0.057	0.006	0.041
Pb	mg/L	0.01		0.2	0.1	5	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Pd	mg/L							0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pr	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Element	Units	WHO: Drinking Water (2022)	WHO: Recreational Use (2021)	IFC: Mining Effluent	RS 109 (2009): Effluent Standards	RS 188 (2013): Irrigation Use	RS 190 (2013): Livestock Watering	Nyanyumba Quartz Vein	Nyanyumba Quartzite	Masoro Schist	Masoro Quartz vein	Masoro Quartzite	Gasambya Schist	Gasambya Quartzite	Gasambya Quartz vein	Mahaza Quartz vein	Mahaza Quartzite	Mahaza Phyllite	Gisanze Quartzite	Gisanze Phyllite	Gisanze Quartz vein	Karambo Fe rich Quartz vein	Karambo Quartzite	Karambo Phyllite	Karambo Quartz vein
Rb	mg/L							0.002	0.007	0.008	0.003	0.001	0.008	0.003	0.002	0.001	0.002	0.005	0.017	0.006	0.001	0.003	0.003	0.004	0.001
SO42-	mg/L						250	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.469	0.500	0.500	0.469
Sb	mg/L	**0.02**						0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Se	mg/L	**0.04**			**0.02**	**0.02**	**0.5**	0.002	0.000	0.000	0.000	0.000	0.008	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.008	0.007	0.005	0.000	0.007
Si	mg/L							2.63	2.64	2.64	2.63	2.64	2.77	2.64	2.64	2.64	2.64	2.64	2.82	2.77	2.63	2.63	2.64	2.64	2.64
Sm	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sn	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	mg/L							0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.007	0.007	0.006
Tb	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Th	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ti	mg/L							0.003	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.007	0.029	0.000	0.000	0.007	0.029	0.000
Tl	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tm	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	mg/L	**0.03**					**0.2**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V	mg/L					**0.1**	**0.1**	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.007	0.007	0.006
W	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Yb	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zn	mg/L			**0.5**	**5**	**2**	**25**	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Zr	mg/L							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
pH				**6-9**	**5-9**		**6-9**	6.11	6.47	6.98	6.16	7.30	8.63	6.34	6.54	6.59	6.81	6.88	8.77	8.64	6.04	5.09	7.00	7.12	6.56

6.0 Soil Results and Interpretations

The soil assessment focused on the downstream areas in relation to the various Rutongo mines footprints. Two locations were identified for the visual soil assessment / classification for each mine, and a soil sample was collected from the most downstream observation point for the required laboratory analysis.

6.1 Soil Classification

Refer to Table 6-1 for the observations and descriptions of the soil classification assessment for the Rutongo mines respectively. The soils in the downstream areas of the various mines were classified as a Ferralsol or Nitisol according to the IUSS Working Group WRB (2022)[5] International Soil Classification System.

Ferralsol

Ferralsols are characterized by a Ferralic horizon which are mainly mineral horizons and are formed because of long and intense weathering. They are common in humid tropical and subtropical regions and often have a red or yellow hue due to the abundance of Fe and Al oxides. These soils are mineralogically characterized by primary Quartz with the clay fraction being dominated by low activity clay minerals (i.e. 1:1 minerals), like Kaolinite, which exhibit a low potential to shrink or swell as well as a relatively low cation exchange capacity. Furthermore, the silt and sand fractions are dominated by highly resistant minerals like Goethite, Hematite and Gibbsite[6].

These soils have a limited capacity to store available water for plants as they are well drained and are often characterized by extensive depths, with stable microstructures that prompt good porosity and infiltration capabilities. Chemically, they are considered poor and infertile as they usually contain low contents of nitrogen, potassium and secondary nutrients like calcium, magnesium and sulphur[7]. This is largely attributed to their susceptibility to leaching, which removes cations from surfaces complexes and contributes to nutrient depletion. Furthermore, these soils are typically acidic and have a low CEC that is pH dependent and can readily fix phosphate by retaining it on soil colloids[3].

Ferralsols can contribute to remediating metal leaching through the retention of metals and metalloids in the terrestrial environment. However, this ability is often insufficient to fully remediate significant contamination concerns and must be coupled with specific management strategies.

It should also be noted that the presence of Fe and Al oxides in Ferralsols plays a key role in regulating the mobility and retention of metals and metalloids[3]. These oxides have variable surface charges and high surface areas which assists in adsorbing metals like Cu, Pb, Zn, Ni, Cr and As. However, the sorbed metals can remobilise if soil pH conditions change to an acidic range.

It should also be noted that Ferralsols have a limited ability to remediate acid rock drainage because of their low CEC and acidic nature. This implies a limited buffering capacity to neutralize acidity that is introduced by acid rock drainage. Consequently, the overall capacity of Ferralsols to remediate metal leaching and acid rock drainage is limited.

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[5] IUSS Working Group WRB. 2022. World Reference Base for Soil Resources. International soil classification system for naming soils and creating legends for soil maps. 4th edition. International Union of Soil Sciences (IUSS), Vienna, Austria.
[6] Deckers, J, Mantel, S, Nachtergaele, F and Vancampenhout, K. 2024. WRB Documentation Centre. Prototype Version 1. Example: Ferralsols.
[7] El Mellouki, M, Boularbah, A and Kebede, F. 2025. “Quantitative evaluation of potentially toxic elements and associated risks in Acrisols and Ferralsols of western Ghana.” *Front. Soil Sci* 01-14.

Nitisol

Nitisols are strongly weathered soils which resemble have similar properties to Ferralsols but are usually more fertile. These soils are deep, well-drained and are characterised by a red hue with diffuse horizon boundaries. Furthermore, the subsurface horizon usually consists of more than 30 percent clay and has a moderate to strong angular blocky structure that breaks easily and is known for its characteristic shiny, polyhedric ('nutty') elements. Although these soils drain freely, their infiltration capacity decreases with depth which is largely affected by textural changes, specifically increased clay contents. This can lead to waterlogged zones in the profile and the development of iron-manganese concretions (i.e. mottles) in deeper layers[8].

The mineralogy of the clay fraction of Nitisols is dominated by Kaolinite and Halloysite with minor proportions of Illite, Vermiculite and randomly interstratified clay minerals. The mineralogical composition of the sand fraction depends on the parent material, although weathering-resistant minerals like Quartz predominate. Furthermore, minor quantities of Feldspars, Apatite, or Amphiboles can be present indicating that Nitisols are less strongly weathered than associated Ferralsols.

Chemically, they are considered moderately fertile as they contain a reasonable amount of organic carbon and nitrogen. Furthermore, these soils are typically acidic (like Ferralsols) but can have a higher cation exchange capacity (CEC). The high CEC is attributed to a higher clay content, despite the clay minerals being low-activity clays (1:1 clay minerals). It is also noted that these soils can fix phosphorus, with acute deficiencies seldomly occurring, unless under poor phosphorus management especially in low input agricultural systems. Generally, they contain sufficient micronutrients but can be deficient in copper and boron[3].

Like Ferralsols, Nitisols can contribute to remediating metal leaching through the retention of metals and metalloids in the terrestrial environment. However, this ability is often insufficient to fully remediate significant contamination concerns and must be coupled with specific management strategies.

It should also be noted that the presence of Fe and Al oxides in Nitisols plays a key role in regulating the mobility and retention of metals and metalloids. These oxides have variable surface charges and high surface areas which assists in adsorbing metals. However, the sorbed metals can remobilise if soil pH conditions change to an acidic range.

[8] Deckers, J, Kimaro, D, Kimaro, O, Njore, R, Nachtergaele, F and Van Ranst, E. 2025. WRB Documentation Centre Nitisols-Lecture Notes. IUSS WRB Working Group webpage and KU-Leuven soil monolith webpage.

Table 6-1: Rutongo Mines Downstream Soil Descriptions and Classification

Mine	Profile ID	Coordinates		Depth (m)	Description	Soil Classification (WRB Reference Soil Group)
		Latitude	Longitude			
Nyanyumba	NYAS-01	1°48'18.3"S	30°03'05"E	0 - 0.05	The soil is moist and populated with numerous fine roots, indicative of the presence of organic material. It has a brown hue and demonstrates a loose granular to blocky structure, with good drainage capability. The transition to the underlying horizon is gradual and marked by a slightly darker hue.	Nitisol
				0.05 - 1.07	The soil is slightly moist with a few medium sized roots visible. The matrix consists of weathered material and is symbolic of a mineral layer. It has a reddish-brown hue and a sandy clay loam texture, with marked clay enrichment from 0.60 m. It demonstrates a massive structure with no distinct structural units. The transition to the underlying horizon is abrupt.	
				1.07 - 1.37	The soil is slightly moist with no roots visible. The matrix consists of weathered material and is symbolic of a mineral layer. It has a reddish-brown hue and a sandy loam texture. It demonstrates a singular grain structure with no distinct structural units.	
	NYAS-02	1°48'19.6"S	30°03'20.9"E	0 - 0.05	The soil is slightly moist and populated with fine to medium sized roots, indicative of the presence of organic material. It has a brown hue and demonstrates a loose granular structure with no rocks/stones present. The transition to the underlying horizon is gradual and marked by a slight increase in the stoniness of the matrix.	
				0.05 - 0.57	The soil is slightly moist and populated with fibrous roots. The matrix contains between 2-10% stones and consists of mainly weathered material, symbolic of a mineral horizon. It has a reddish-brown hue, sandy loam texture, and massive structure with no apparent structural units. It has good drainage capability and an abrupt transition to the underlying horizon due to clay accumulation.	
				0.57 - 1.02	The soil is slightly moist, and the matrix contains between 20-30% stones as well as consists of mainly weathered material. It has a reddish-brown hue and contains more clay than the overlying material. It has a sandy clay loam texture with a platy structure due to the higher clay content at the bottom of the profile. Refusal was intersected at 1.02 m and auguring was aborted.	

Note: A soil sample was obtained from NYAS-02 for the laboratory analysis.

Rutongo Mines Downstream Soil Descriptions and Classification Cont.

<table>
<tr><th rowspan="2">Mine</th><th rowspan="2">Profile ID</th><th colspan="2">Coordinates</th><th rowspan="2">Depth (m)</th><th rowspan="2">Description</th><th rowspan="2">WRB Reference Soil Group</th></tr>
<tr><th>Latitude</th><th>Longitude</th></tr>
<tr><td rowspan="6">Masoro</td><td rowspan="4">MAS-01</td><td rowspan="4">1°49’57.2”S</td><td rowspan="4">30°02’39.8”E</td><td>0 - 0.10</td><td>The soil is slightly moist with a matted root structure, indicative of the presence of organic material. It has a dark brown hue and demonstrates a loose granular structure with no rocks/stones present in the matrix. The transition to the underlying horizon is gradual and marked by an increase in stoniness of the matrix.</td><td rowspan="4">Nitisol</td></tr>
<tr><td>0.10 - 0.61</td><td>The soil is slightly moist and contains between 2-10% stones. It consists of mainly weathered material, symbolic of a mineral horizon and is characterized by a reddish-brown hue, clay loam texture with a sub-angular blocky structure. It has good drainage capability and gradually transitions into the underlying horizon. There are indications of saprolite from 0.7 m.</td></tr>
<tr><td>0.61 - 0.70</td><td>The soil is slightly moist and contains between 2-10% stones. It consists of mainly weathered material, symbolic of a mineral horizon and is characterized by an orange-brown hue, clay loam texture with a massive structure with no apparent structural units. There is a gradual transition to the underlying material.</td></tr>
<tr><td>0.70 - 1.05</td><td>The soil is slightly moist and shows an abrupt textural transition, due to a significant clay accumulation. The soil texture is predominantly clay and has a brown hue. The mass demonstrates a sub-angular blocky structure with a polyhedral unit as a sub-structure, which is typical of high clay content soils.</td></tr>
<tr><td rowspan="2">MAS-02</td><td rowspan="2">1°50’05.3”S</td><td rowspan="2">30°02’42.5”E</td><td>0 - 0.05</td><td>The soil is slightly moist with a fibrous root system. No rocks/stones were present in the matrix. It has a light brown hue and demonstrates a massive structure with no distinct structural units. The transition to the underlying material is gradual.</td><td rowspan="2">Ferralsol</td></tr>
<tr><td>0.05 - 0.34</td><td>The soil has a sandy loam texture, with signs of clay accumulation towards the bottom of the horizon. The matrix contains about 2-10% stones and has a reddish-brown hue. The structure resembles a singular grain structure, typical of structureless soil, with a high sand fraction. Refusal was intersected at 0.34 m (potentially a pebble marker) and auguring was aborted.</td></tr>
</table>

Note: A soil sample was obtained from MAS-02 for the laboratory analysis.

Rutongo Mines Downstream Soil Descriptions and Classification Cont.

Mine	Profile ID	Coordinates		Depth (m)	Description	WRB Reference Soil Group
		Latitude	Longitude			
Gasambya	GAS-01	1°47’40.1”S	30°03’21.9”E	0 - 0.05	The soil is dry with no roots present and shows characteristics of an organo-technic material. The matrix contains about 2-10% stones and shows a cohesionless structure. The transition to the underlying horizon is gradual and it is possible that it could be taken as a complete sequence.	Ferralsol
				0.05 - 0.24	The soil has a sandy loam texture and contains a higher stone fraction than the overlying layer (20-30%). It has a red-brown hue with a massive structure, with a singular grain sub-structure. This is typical of structureless soil, with a high sand fraction. Refusal was intersected at 0.24 m and auguring was aborted.	
	GAS-02	1°47’50.6”S	30°03’36.6”E	0 - 0.09	The soil is slightly moist with several fine roots, and no stones present in the mass. It has a dark brown hue and gradually transitions to the underlying horizon.	Nitisol
				0.09 - 0.50	The soil is slightly moist and contains a higher stone fraction than the overlying layer. It is estimated that the matrix contains between 10-20% stones. It has a red-brown hue as well as a sandy clay loam texture. It shows the characteristics of a massive structure with no distinct structural units. The transition to the underlying horizon is abrupt as marked by a distinct textural change.	
				0.50 - 0.84	The soil is slightly moist and has a brown hue. It has a clay loam texture and shows a polyhedral structure, which is typical of high clay content soils.	

Note: A soil sample was obtained from GAS-02 for the laboratory analysis.

Rutongo Mines Downstream Soil Descriptions and Classification Cont.

<table>
<tr><th rowspan="2">Mine</th><th rowspan="2">Profile ID</th><th colspan="2">Coordinates</th><th rowspan="2">Depth (m)</th><th rowspan="2">Description</th><th rowspan="2">WRB Reference Soil Group</th></tr>
<tr><th>Latitude</th><th>Longitude</th></tr>
<tr><td rowspan="5">Mahaza</td><td rowspan="3">MHS-01</td><td rowspan="3">1°47’25.5”S</td><td rowspan="3">30°04’55.8”E</td><td>0 - 0.10</td><td>The soil is slightly moist with medium-sized roots. No stones are present in the mass, and it has a dark brown hue. There is a gradual transition to the underlying material.</td><td rowspan="3">Nitisol</td></tr>
<tr><td>0.10 - 0.70</td><td>The soil is slightly moist and contains between 2-10% stones. It consists of mainly weathered material, symbolic of a mineral horizon and is characterized by a reddish-brown hue, silty clay loam texture with a massive structure without distinct structural units. It has good drainage capability. The transition into the underlying material is abrupt.</td></tr>
<tr><td>0.70 - 1.10</td><td>The soil is slightly moist with no roots visible. The matrix consists of weathered material and contains about 10-20% stones. It has a reddish-brown hue and a sandy loam texture. It demonstrates a massive structure with no distinct structural units. There was some Mn mottles present towards the bottom of the horizon but did not qualify as a gleyic horizon. Clay content seemed to decrease towards the bottom of the horizon.</td></tr>
<tr><td rowspan="2">MHS-02</td><td rowspan="2">1°47’44.3”S</td><td rowspan="2">30°04’54.0”E</td><td>0 - 0.05</td><td>The soil is slightly moist and populated with a mated root structure, indicative of the presence of organic material. It has a light brown hue and gradually transitions to the underlying material.</td><td rowspan="2">Ferralsol</td></tr>
<tr><td>0.05 - 0.30</td><td>The soil is slightly moist and contains more than 30% of the volume stones. It has a light brown hue and demonstrates a massive, cohesionless structure. Refusal was intersected at 0.30 m due to numerous rock fragments and auguring was aborted. Surrounding exposed soils show signs of a shallow pebble marker.</td></tr>
</table>

Note: A soil sample was obtained from MHS-02 for the laboratory analysis.

Rutongo Mines Downstream Soil Descriptions and Classification Cont.

Mine	Profile ID	Coordinates		Depth (m)	Description	WRB Reference Soil Group
		Latitude	Longitude			
Gisanze	GSS-01	1°46'21.9"S	30°01'11.8"E	0 - 0.11	The soil is dry and contains some medium sized roots. It has a light brown hue and gradually transitions to the underlying horizon. It contains 10-20% stones and has a sandy loam texture. The matrix consists of mainly weathered material, typical of a mineral horizon.	Ferralsol
				0.11 - 0.64	The soil is slightly moist and consists of mainly weathered material which is symbolic of a mineral layer. It contains about 2-10% stones and has a reddish-brown hue. It demonstrates a sandy clay loam texture, with a sub-angular blocky structure and shows good drainage capability. The transition to the underlying material is gradual.	
				0.64 - 1.27	The soil is slightly moist and has a red-brown hue. There is marked clay accumulation in this horizon compared to the overlying horizon. It has a sandy clay texture and is characterized by an angular blocky structure with most of the peds showing flat faces. This is common of clay rich sub-soil B horizons.	
	GSS-02	1°46'20.1"S	30°01'12.9"E	0 – 0.06	The soil is slightly moist to damp with 2-10% stones in its matrix. It is characterized by a sparse matted root structure symbolizing an organic horizon. It has a dark brown hue and abruptly transitions to the underlying material due to a distinct soil texture variation.	Nitisol (with gleyic properties)
				0.06 – 0.20	The soil is wet with a grey-brown hue. The soil texture is predominantly clayey and has an angular block texture. The transition to the underlying horizon is gradual. There is limited drainage capability associated with this observation point as water was ponded on the surface in proximity to the auger hole.	
				0.20 – 0.84	The soil is wet with a grey-brown hue, has a texture that is clayey and a soil structure that is angular blocky. A few iron mottles were identified in the soil mass towards the bottom of the horizon which is indicative of signs of wetness. Thus, the horizon resembles gleyic properties which suggest that there is a very-high fluctuating water table. It should be noted that the observation point is located on a toe slope, close to a river.	

Note: A soil sample was obtained from GSS-02 for the laboratory analysis.

Rutongo Mines Downstream Soil Descriptions and Classification Cont.

Mine	Profile ID	Coordinates		Depth (m)	Description	WRB Reference Soil Group
		Latitude	Longitude			
Karambo	KSS-01	1°46'07"S	30°03'20.6"E	0 – 0.02	The soil is dry and has a pale brown hue with 2-10% stone fraction in its matrix. Very little organic material is present but has some grass cover.	Ferralsol
				0.02 – 0.39	The soil is dry and characterized by a pale brown hue almost resembling a bleached horizon. It has a 20 – 30 % stone fraction in its matrix which consists of mainly weathered material. It has a sandy loam soil texture with good drainage capability and a massive structure without distinct structural units.	
				0.39 – 0.85	The soil is slightly moist and has a red-brown hue with a sandy clay loam texture. It shows good drainage capability and a slightly higher clay content than the overlying horizon. The transition to the underlying material is gradual.	
				0.85 – 1.31	The soil is slightly moist and consists of mainly weathered material which is symbolic of a mineral layer. It contains about 2-10% stones and has a dark brown hue. It shows a sandy clay loam texture, with a sub-angular blocky structure. There were a few black specs in the soil matrix at the bottom of the layer which are likely to be Mn mottles.	
	KSS-02	1°46'13.4"S	30°03'44.4"E	0 – 0.05	The soil is slightly moist and populated with fine roots, indicative of the presence of organic material. It has a brown hue and demonstrates a loose cohesionless structure, with good drainage capability. The transition to the underlying material is gradual.	
				0.05 – 1.60	The sub-soil horizon is very deep and thick, is characterized by a red-brown hue with a silty clay to sandy clay loam texture which is typical of soils in tropical regions. There are a few medium sized roots present in the soil matrix. It has good drainage capability and shows a massive soil structure with no distinct structural units. There is some clay accumulation at the bottom.	

Note: A soil sample was obtained from KSS-02 for the laboratory analysis.

6.2 Physicochemical Soil Properties

Table 6-2 below shows the physicochemical properties of the downstream soil samples that were analysed as part of the Rutongo mines soil assessment.

The Rutongo mines soil samples are characterised by a higher percentage of sand (>50%) compared to the silt and clay fractions. The dominance of the sand fraction in all the soil samples shows that they are likely to have good porosity and infiltration capabilities as per the characteristics of Ferralsol and Nitisol soils. However, it should be noted that drainage can decrease with depth due to increased clay content, especially for Nitisols. It is also reported that most of the soils have a sandy loam texture except for the downstream Masoro soil sample which has a sandy clay loam texture. This soil sample also reported the highest clay percentage for the various Rutongo mines.

All soil samples reported low organic carbon contents (0.70 – 1.40%) which could be attributed to the rapid decomposition of organic matter due to the climate of the region. Furthermore, the lack of high activity clay minerals (i.e. 2:1 minerals) that are not commonly associated with Ferralsols and Nitisols, as well as the abundance of Fe and Al oxides can contribute to the low organic carbon content as the oxides do not tend to complex with organic carbon. This implies that the Rutongo mines soil samples are likely to have a limited acid buffering capacity, making them prone to acidification.

The pH range of the Rutongo soil samples is acidic (4.78 to 5.31). This is typical of Ferralsols and Nitisols with Ferralsols being susceptible to nutrient leaching. Furthermore, these pH levels suggests that there will be a reduced availability of essential nutrients like N, K, Ca and Mg and certain trace and heavy metals can become available at this pH level, resulting in potentially phytotoxic levels. The soils show very low CECs (<10 cmol+/kg) which implies that the soils are unlikely to buffer changes against pH. The low CEC values are attributed to their acidic pH levels as there are fewer exchangeable ions available on the surface with more H^+ ions found at the reaction sites.

Table 6-2: Rutongo Mines Downstream Soil Physicochemical Properties

Mine	Sample ID	Particle size (%)			Soil Texture Class	Density (g/cm^3)	Organic Carbon (%)	pH (H_2O)	EC (µS/cm)	Cation Exchange Capacity (cmol$_c$/kg)
		Sand	Silt	Clay						
Nyanyumba	NYAS-02	65	20	15	Sandy Loam	1.13	1.10	5.01	74	3.08
Masoro	MAS-02	60	17	23	Sandy Clay Loam	1.09	1.10	5.31	62	2.97
Gasambya	GAS-02	63	26	11	Sandy Loam	1.25	0.80	5.1	36	2.84
Mahaza	MHS-02	66	23	11	Sandy Loam	1.12	0.90	4.78	38	2.05
Gisanze	GSS-02	53	24	11	Sandy Loam	1.01	1.40	4.88	41	2.78
Karambo	KSS-02	71	14	15	Sandy Loam	1.17	0.70	5.29	66	2.24

6.3 Nutrient Status

Table 6-3 shows the primary, secondary and micro-nutrient status of the downstream soil samples that were analysed as part of the Rutongo mines soil assessment. The purpose of determining the soils nutrient status is not to provide a fertilizer recommendation but to provide an indication of the availability of nutrients in the soil. For this assessment, the Mehlich 3 (Mehlich, 1984)[9] extraction was used to determine the plant available (i.e. bio-available) nutrient status of the downstream soils.

Based on the available nutrient status, most of the soil samples are characterised by relatively low proportions of P (<10 mg/kg) and K (<50 mg/kg) as primary nutrients, except for the Gisanze soils which contains an acceptable amount of P. Furthermore, the Ca and S contents are below the general range associated with these nutrients but the Mg contents for some of the soils are considered appropriate except for the Gasambya, Mahaza and Gisanze soils, which are below the general range that is suitable for most crops (50 – 120 mg/kg). In terms of the micro-nutrient status, none of the soils show excessive trace metal contents that could lead to phytotoxicity risks. It is also noted that the relatively high Fe status is likely attributed to the abundance of Fe oxides associated with Ferralsols and Nitisols, while the Mn levels are likely to be derived from the parent material.

[9] Mehlich, A. (1984) Mehlich 3 Soil Test Extractant. A Modification of the Mehlich 2 Extractant. Communications in Soil Science and Plant Analysis, 15, 1409-1416.

Table 6-3: Rutongo Mines Downstream Soil Nutrient Status

Mine	Sample ID	Nutrient Status (mg/kg)													
		Primary		Secondary			Trace								
		P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B	Mo	Co	Si	Ni
Nyanyumba	NYAS-02	2.00	19	195	54	8.99	87.82	26.63	2.86	1.64	0.17	0.06	0.02	75.6	0.06
Masoro	MAS-02	5.00	23	281	66	7.87	118.76	21.34	1.93	1.21	0.53	0.01	0.01	48.9	0.04
Gasambya	GAS-02	2.00	22	101	31	8.63	75.39	26.73	1.98	1.34	0.14	0.07	0.03	49.6	0.03
Mahaza	MHS-02	2.00	28	149	39	7.53	121.96	20.73	1.06	1.46	0.33	0.22	0.01	50.9	0.04
Gisanze	GSS-02	14.00	19	167	33	10.53	410.5	122.48	3.7	3.51	1.29	0.07	0.04	67.6	0.10
Karambo	KSS-02	6.00	22	172	67	12.77	122.58	26.61	1.82	1.42	0.42	0.04	0.02	39.7	0.04

Note: N could not be determined by the M3 extraction.

6.4 Total Metal Concentrations

Table 6-4 shows the total metal concentration results that were screened against the SSV1 (all land uses) thresholds to assess if any element is a potential contaminant in the downstream soil sample. Based on the total metal concentration results, the following exceedances are reported for the Rutongo mines downstream soil samples and could be potential COCs.

Gisanze Mine:

- Cu
- Mn

The elevated Cu and Mn concentrations of the Gisanze soil sample is suggested to be derived from the mineralogy of the parent material from which the soil originates and is not necessarily due to mining activities, impacting the downstream areas.

Table 6-4: Rutongo Mines Downstream Soil Total Metal Concentration Screening Results

Mine	Analytes	Ag	As	B	Ba	Be	Bi	Cd	Co	Cr (total)	Cu	Ge	Hg	Mn	Mo	Nb	Ni
	Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
	SSV1 (All Land Uses Protective of the Water Resource)		**5.8**					**7.5**	**300**		**16**		**1**	**740**			**91**
Nyanyumba	NYAS-02	1.40	<0.01	0.79	19.62	0.64	<0.01	<0.01	1.34	25.89	12.23	2.30	<0.01	189	<0.01	9.01	3.20
Masoro	MAS-02	0.80	<0.01	0.12	27.57	0.33	<0.01	<0.01	2.77	24.20	10.35	3.80	<0.01	208	<0.01	7.88	3.31
Gasambya	GAS-02	1.50	<0.01	0.68	14.47	0.49	<0.01	<0.01	1.21	33.53	8.67	2.20	<0.01	158	<0.01	7.11	0.53
Mahaza	MHS-02	1.30	<0.01	0.15	14.94	0.29	<0.01	<0.01	0.96	17.02	9.69	1.90	<0.01	87	<0.01	4.77	1.32
Gisanze	GSS-02	0.70	<0.01	0.97	165.34	1.38	<0.01	<0.01	10.54	24.14	23.48	8.00	<0.01	1427	<0.01	17.18	12.89
Karambo	KSS-02	4.80	<0.01	0.65	22.74	0.54	<0.01	<0.01	1.62	15.85	12.56	2.60	<0.01	276	<0.01	7.10	3.13

Mine	Analytes	Pb	Pd	Sb	Se	Si	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	Zn	Zr
	Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
	SSV1 (All Land Uses Protective of the Water Resource)	**20**													**150**	**240**	
Nyanyumba	NYAS-02	3.25	211	<0.01	<0.01	101	<0.01	5.43	<0.01	<0.01	13.49	213	<0.01	37.96	37.96	25.35	2.5
Masoro	MAS-02	5.93	270	<0.01	<0.01	121	<0.01	6.91	<0.01	<0.01	12.44	272	<0.01	61.04	39.38	25.33	5.4
Gasambya	GAS-02	2.28	169	<0.01	<0.01	85	<0.01	2.52	<0.01	<0.01	10.62	169	<0.01	59.20	52.17	8.41	1.7
Mahaza	MHS-02	0.27	139	<0.01	<0.01	96	<0.01	4.47	<0.01	<0.01	9.23	140	<0.01	40.45	17.00	16.76	2.3
Gisanze	GSS-02	5.16	178	<0.01	<0.01	102	<0.01	6.76	<0.01	<0.01	29.68	183	<0.01	157.06	33.27	73.32	3.4
Karambo	KSS-02	6.10	209	<0.01	<0.01	94	<0.01	4.95	<0.01	<0.01	8.99	210	<0.01	46.60	24.05	21.74	1.8

7.0 Summary

The following has been undertaken:

- A geochemical baseline assessment of the river sediments to determine their capacity to remediate any metal leaching and acid rock drainage that might be emanating from the legacy tailings lithologies, and
- A geochemical baseline assessment of the legacy tailings lithologies that are integrated with the Rutongo mines to determine their acid rock drainage and metal leaching potential risk,
- A baseline assessment of the downstream soils to assess their physical and chemical properties and their capacity to remediate any metal leaching and acid rock drainage risks that might be emanating from the legacy tailings lithologies.

River Sediment Assessment

Overall, the Rutongo mines upstream river sediment samples are characterised by the highest gravel fraction and lowest silt fraction, with minor to negligible differences in the clay fractions between the sediment sampling positions. Furthermore, the sand fraction is the dominant particle size fraction for most of the sediment sampling position which suggests that the hydrological functioning of the river systems has been altered.

The XRD results show that Quartz is the dominant mineral in the river sediment samples with major to minor proportions of Muscovite. There are also minor proportions of Kaolinite and Schorl with minor to trace amounts of Hematite present.

Due to the presence of Hematite, Schorl, Kaolinite and Muscovite in the sediments, it is suggested that they can sequester metals and metalloids that are mobilised by historic and current mining activities occurring in the vicinity of the river. This infers that the sediments are likely to show an enrichment / accumulation of various metals that exceed average crustal abundances or background level values.

The SPLP test noted the following analytes as potential COPCs for the river sediments obtained from each mine when compared to national and international water guidelines as follows:

Nyanyumba Mine: Fe (downstream), Mn (both) and pH (downstream)

Masoro Mine: As (downstream), Mn (downstream), Fe (downstream) and pH (both)

Gasambya Mine: Fe (upstream), Mn (downstream) and pH (both)

Mahaza Mine: Mn (both) and pH (both)

Gisanze Mine: Fe (both), Mn (both), Pb (upstream) and pH (downstream)

Karambo Mine: As (downstream), Fe (both), Mn (downstream) and pH (downstream)

The total metal concentration results reported the following exceedances of the SSV1 (all land uses) limits for the river sediments obtained from each mine:

Nyanyumba Mine: As and Pb (both)

Masoro Mine: As (both), Cu (upstream) and Pb (upstream)

Gasambya Mine: As (both), Cu (upstream), Pb (upstream) and V (upstream)

Mahaza Mine: As (both), Cu (downstream) and Pb (both)

Gisanze Mine: As (both) and Pb (both

Karambo Mine: As (both), Cu (downstream) and Pb (both)

The exceedances of the SSV1 limits for the various metals in the sediments show that anthropogenic activities have likely impacted the rivers in the vicinity of the Rutongo mines. This is likely attributed to historic and current panning activities, runoff from the legacy tailings piles and illegal mining activities along the rivers.

The GAI values were compared to the estimated average crustal abundance of the various elements to assess the significance of elemental enrichment in the river sediments obtained from each mine to determine the likelihood of contamination. Based on the calculated GAI values of the metals that were analysed, the following is noted:

Nyanyumba Mine:

B, Bi and Se show a GAI>3

As shows a GAI>6

Masoro Mine:

As, B and Se show a GAI>3

As shows a GAI>6

Gasambya Mine:

B and Se show a GAI>3

As shows a GAI>6

Mahaza Mine:

As and B shows a GAI>3

Gisanze Mine:

As and Sn show a GAI>3

B shows a GAI>6

Karambo Mine:

Ag, As, Bi and Sn show a GAI>3

As, B and Pd shows a GAI>6

The geochemical baseline assessment of the Rutongo mines river sediments exhibits a geochemical character that has a limited potential to remediate ARD mainly due to the absence of primary and secondary neutralizing minerals. However, the sediments possess some potential to remediate metal leaching risks because of the presence of Hematite, Schorl, Kaolinite and Muscovite which can facilitate the adsorption of metal ions on their surfaces.

Legacy Tailings Assessment

The Nyanyumba Quartz vein consists entirely of Quartz whereas the Quartzite is dominated by Quartz with major proportions of Muscovite. The Masoro Schist is dominated by Muscovite with major proportions of Quartz and minor proportions of Kaolinite and Dravite. The Masoro Quartz vein consists entirely of Quartz whereas the Masoro Quartzite is dominated by Quartz with minor proportions of Kaolinite and trace proportions of Muscovite.

The Gasambya Schist is dominated by Muscovite with major proportions of Quartz and minor proportions of Palygorskite and Kaolinite. The Gasambya Quartzite consists of mainly Quartz with minor proportions of Dravite and trace proportions of Muscovite. Lastly, the Gasambya Quartz vein consists entirely of Quartz.

The Mahaza Quartz vein contains only Quartz whereas the Quartzite is dominated by Quartz with major proportions of Kaolinite and minor proportions of Muscovite and Goethite. The Mahaza Phyllite is dominated by Muscovite with major proportions of Quartz and minor proportions of Kaolinite and Hematite respectively.

The Gisanze Quartzite is dominated Quartz with major proportions of Muscovite and minor proportions of Kaolinite and Palygorskite as well as trace proportions of Dravite. The Phyllite is dominated by Muscovite with major proportions of Quartz and minor proportions of Palygorskite and Dravite. Lastly, the Gisanze Quartz vein comprises entirely of Quartz.

The Karambo Fe rich Quartz vein is dominated by Goethite and Quartz whereas the Quartz vein consists entirely of Quartz. The Karambo Phyllite is dominated by Muscovite with minor proportions of Quartz and Kaolinite. Lastly, the Karambo Quartzite is dominated by Quartz with minor proportions of Kaolinite and Muscovite.

The XRD analyses did not detect the presence of acid producing minerals (like sulfides) in any of the Rutongo mines legacy tailings lithologies suggesting that they are likely to be non-potential acid generating with a minimal to low acid rock drainage (ARD) risk.

However, the ABA analyses classified majority of legacy tailings samples as PAG, 5 Intermediate with only one non-PAG lithology.

The PAG lithologies reported moderately acidic to alkaline paste pH values with NPR values less than 1 and NNP values between -20 and 20. The intermediate potential to generate acid lithologies reported moderately acidic to slightly alkaline paste pH values with NPR values which varies from less than 1 to between 1 and 4 and NNP values between -20 and 20. The non-PAG lithologies reported moderately acidic paste pH values with NPR values which varies from greater than 4 to between 1 and 4 respectively and NNP values between -20 and 20.

The low NPR and NNP values for the Rutongo mines legacy tailings lithologies are not due to an abundance of acid generating minerals (like Pyrite) but rather because of the lack of rapidly dissolving neutralising minerals like carbonates in the materials.

The SPLP tests detected several exceedances of the national and international water quality guidelines for the various legacy tailings lithologies at the Rutongo mines as COPCs as follows:

Nyanyumba Mine: Mn (Quartz Vein and Quartzite)

Masoro Mine: Mn (Quartz Vein and Quartzite) and pH (Schist and Quartz Vein)

Gasambya Mine: As (Quartz Vein), Fe (Quartz Vein), Mn (Quartzite and Quartz Vein) and pH (Quartzite)

Mahaza Mine: Mn (Quartz Vein) and pH (Quartzite)

Gisanze Mine: Mn (Quartz Vein) and pH (Phyllite and Quartz Vein)

Karambo Mine: As (Fe Rich Quartz Vein), Mn (Fe Rich Quartz Vein and Quartz Vein) and pH (Fe Rich Quartz Vein and Quartzite).

Similarly, the geochemically modelled source terms predict the following exceedances of the national and international thresholds for the tailings lithologies at the Rutongo mines.

Nyanyumba Mine: Mn (Quartz Vein and Quartzite)

Masoro Mine: Mn (Quartz Vein and Quartzite)

Gasambya Mine: As (Quartz Vein), Fe (Quartz Vein) and Mn (Quartzite and Quartz Vein)

Mahaza Mine: Mn (Quartz Vein)

Gisanze Mine: Mn (Quartz Vein)

Karambo Mine: As (Fe Rich Quartz Vein), Mn (Fe Rich Quartz Vein, Quartzite and Quartz Vein) and pH (Fe rich Quartz Vein).

The geochemical baseline assessment of the Rutongo legacy tailings lithologies exhibits a geochemical character that indicates a potential risk for ARD mainly due to a lack of neutralising minerals as opposed to the abundance of acid producing minerals (like Pyrite) in the materials. Furthermore, the lithologies pose a high risk for metal leaching, which could potentially impact the environment as several metals were identified and modelled as COPCs.

Soil Assessment

The soil assessment of the downstream areas at the Rutongo mine footprints, classified the soils as Ferralsols and Nitisols, characterised by a higher percentage of sand compared to the silt and clay fractions. The dominance of the sand fraction shows that they are likely to have good porosity and infiltration capabilities. It is also reported that most of the soils have a sandy loam texture except for the downstream Masoro soil sample which has a sandy clay loam texture.

Ferralsols are mineralogically characterized by Quartz, Kaolinite, Goethite, Hematite and Gibbsite whereas Nitisols also comprise these minerals in addition to Halloysite with minor proportions of Illite, Vermiculite, Feldspars, Apatite or Amphiboles depending on their parent material. Both soils are characterised by the presence of Fe and Al oxides can contribute to metal adsorption and remediation of metal leaching.

All soil samples reported low organic carbon contents which implies that they have a limited acid buffering capacity making it prone to acidification and nutrient leaching. The pH of the Rutongo mines soil samples is acidic and are likely susceptible to nutrient leaching with a reduced availability of several essential nutrients. The soils show very low CECs which implies that the soils are unlikely to buffer changes against changes in pH. Furthermore, Cu and Mn exceed the SSV1 thresholds for the Gisanze downstream soil sample and therefore COPCs. However, we infer that the elevated Cu and Mn concentrations are derived from the mineralogy of the parent material and is not necessarily due to mining activities.

The soil baseline assessment shows that Ferralsols and Nitisols have a limited capacity to remediate metal leaching and ARD potential. This is largely due to their low CEC, acidic nature and consequently limited buffering capacity. However, this ability can be improved with specific management strategies like soil liming, especially if they are impacted by ARD.

Recommendations

Notwithstanding the findings of this study, SLR would like to recommend the following:

1. Undertake a comprehensive static geochemical assessment of the Rutongo mines individual legacy tailings piles to determine each piles acid rock drainage and metal leaching potential risk to develop a risk register for each mine to inform the remediation of high-risk legacy tailings piles.
2. Undertake a comprehensive static geochemical assessment of the individual particle size fractions of the river sediments to delineate which fraction is most contaminated to identify suitable remediation options as part of the rehabilitation process.

Regards,

SLR Consulting (Africa) Proprietary Limited

Vibhishan Moodley, MSc
Geochemistry Consultant, MEA
Author

Dr Andrea Baker, PhD
Associate Geochemist, MEA
Technical lead / Reviewer

Stephen Weber, MSc
Service Line Director: Earth Sciences, MEA