NOWA NOWA IRON PROJECT

ATTACHMENT 6 :

ENVIRONMENTAL GEOCHEMICAL ASSESSMENT OF WASTE AND ORE

Prepared for Eastern Iron Limited by Earth Systems

REVISION 3

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Executive Summary

Earth Systems was engaged by Eastern Iron Limited to undertake a geochemical assessment of geological mine materials for the proposed Nowa Nowa Iron Project, eastern Victoria and to develop appropriate operations and post-closure management strategies. This work forms part of an environmental assessment conducted as part of an EES Referral.

Eastern Iron, through its wholly owned subsidiary Gippsland Iron Pty Ltd, proposes to develop the 5 Mile magnetite/haematite deposit located approximately 7 km north of the town of Nowa Nowa. The site is located in State Forest with a history of timber harvesting, and within the catchment of Boggy Creek and Lake Tyers, which is located approximately 15 km downstream of the proposed mine site.

The 5 Mile deposit consists of a massive magnetite ore body within Silurian felsic volcanics (Thorkidaan Volcanics), turbidites and limestone. The ore is to be processed on site by dry low intensity magnetic separation (LIMS). It is estimated that the 5 Mile deposit would produce 8 Mt of magnetite product, 2 Mt of low-grade ore, and 24 Mt of waste rock over an operating term of 10 years. The proposed operation comprises an open pit, a processing plant, a waste rock dump, a temporary low-grade ore stockpile, three water management storages, site administration facilities and associated infrastructure.

The geochemical assessment of mine materials involved a review of available data, a site visit by Earth System geochemical specialists, the selection and collection of representative samples of waste rock and ore from available core material, and the static and kinetic geochemical analysis of the selected sample set. A total of 37 intervals of representative lithologies of waste rock and 10 ore intervals were selected for assessment, supplemented by historical sulfur data for 377 historical ore intervals, and data from preliminary dry LIMS metallurgical testwork. Kinetic geochemical testwork was performed on two waste rock samples and one LIMS sample, and simulated kinetic geochemistry was obtained for average compositions of key waste rock lithologies and ore categories.

The geochemical assessment identified the following categories of waste rock:

- Category A: Non acid forming (NAF) materials not requiring special management. Most waste rock from all lithologies falls into this category (total approx. 18.5 Mt).
- Category B: Potentially acid forming (PAF) materials with marginal to low acid producing potential requiring specific consideration for disposal. A small proportion of hangingwall volcanics (<10%) and footwall sediments (~25%) fall into this category (total approx. 2.7 Mt).
- Category C: Potentially acid forming (PAF) materials with moderate acid producing potential requiring special management. A small proportion of footwall sediments (~25%) fall into this category (total approx. 1.2 Mt).
- Category N: Potentially acid consuming materials that can be used to assist with management of Category B and C materials. Footwall limestone and a small proportion of footwall sediments (~25%) fall into this category (total approx. 1.6 Mt).

The following categories of ore and product materials were also characterised for the purpose of material management:

- ROM ore: Potentially acid forming (PAF) with moderate acid production potential.
- Dry LIMS product: Potentially acid forming (PAF) with moderate acid production potential.
- Low-grade ore: Potentially acid forming (PAF) with high acid producing potential requiring special management.

Specific management strategies for each waste rock management category and ore materials were developed and incorporated into the Mine Plan. The mine plan includes the following key strategies for the management of geochemical stability:

Operations

- There is no tailings storage facility (TSF).
- Sulfidic materials (Category C waste rock and unsold low-grade ore) are to be temporarily stockpiled in Tomato Creek upstream of the pit. Drainage from the stockpile is to be collected in a sump for treatment (if necessary) and reuse onsite. Excess drainage from the temporary stockpile exceeding pump capacity ultimately reports to the open pit.
- A waste rock dump containing only Category A, B and N waste rock materials is to be constructed in Gap Creek upstream of the pit. Drainage from the dump is to be collected in a sump for treatment (if necessary) and reuse on site. Any excess drainage from the dump exceeding pump capacity ultimately reports to the open pit.
- The waste rock dump is to be constructed in thin horizontal lifts by truck dumping with compaction, and Category B materials are to be encapsulated within Category A and N materials to inhibit sulfide oxidation and potential release of acid drainage in the long term.
- Three water storages are to be constructed to facilitate management of site drainage, an Operations Water Storage located immediately downstream of the pit on Tomato Creek, a Clean Water Storage downstream of mine infrastructure on Tomato Creek, and a Sediment Control Dam downstream of mine infrastructure on Tomato Creek.
- The Operations Water Storage has a minimal direct catchment and is designed to accpeted pumped drainage from collections sumps in the pit, waste rock dump, ROM pad and stockyard, and the temporary low-grade ore stockpile and Category C waste rock pile. The storage and its management are designed for zero discharge downstream, and all contained drainage is to be treated (if necessary) and reused in ore processing and dust suppression. All drainage inputs to the Operations Water Storage are pumped, providing effective control on storage water level.
- Geochemical assessment indicates that ROM ore and the dry LIMS product have sufficient acid neutralising capacity to inhibit the formation of acid drainage for 2–3 years. Drainage from the ROM pad and stockyard is likely to be of near-neutral pH but present with elevated salinity and dissolved metal concentrations and is therefore to be captured in a sump and pumped to the Operations Water Storage.

Post Closure

- The mine pit is designed to flood on mine closure, and to overflow regularly into Tomato Creek with a significant long-term positive water balance. The overflow level of the pit lake is approximately 190 mAHD, marginally higher than the premining peak groundwater level in the pit area (approx. 187 mAHD). The volume of the pit lake will be approximately 6 GL.
- Temporarily stockpiled sulfidic materials (Category C waste rock and unsold low-grade ore) are to be backfilled into the open pit on mine closure for storage under a permanent water cover (minimum 2 m, estimated to be > 100 m in the long term) to prevent oxidation. Organic matter and limestone (if necessary for pH adjustment on flooding) are to be added to the pit after backfilling to provide long-term passive treatment capacity.
- To minimise the period that sulfidic materials and wall rock will be exposed to atmospheric oxygen in the pit as it is flooded, natural inflows from the upstream catchment and groundwater rebound are to be augmented by pumping clean catchment water from the Clean Water Storage

and Sediment Control Dam at least until a minimum 2 m water cover has been established over the backfilled sulfidic materials.

- The pit lake is designed to provide passive treatment for all inflows (ie. from the waste rock dump, wall rock and groundwater) through a combination of retention time, sulfate reduction by sulfate reducing bacteria (SRB), and acid neutralisation by alkalinity produced by SRB activity and the dissolution of limestone, and alkalinity brought in by groundwater.
- The Operations Water Storage and Clean Water Storage are to be partially decommissioned as wetlands to provide two stages of passive treatment for outflows from the pit lake. The Sediment Control Dam is to be decommissioned and the water course rehabilitated.
- The amount of runoff reporting to the open pit post-closure is to be maximised by fully rehabilitating Tomato Creek upstream of the pit and by completing the waste rock dump with a cover system that minimises the infiltration of water into the dump and maximises runoff generation. The area of the top surface of the waste rock dump is to be maximised and graded to the east to allow all runoff to be captured at the upstream end of Gap Creek and diverted into the adjacent Tomato Creek catchment (using the new topography). Impermeable materials for the cover system can be sourced from the mine water storages as they are decommissioned.
- After flooding, the pit will have highwalls of 30–40 m in height (above the pit lake water level) on the western and eastern sides exposing volcanics. No acid drainage from these highwalls is expected. All drainage from the exposed highwalls reports to the pit for passive treatment.

Incorporation of management for geochemical stability into the mine plan results in a management strategy with extremely low residual risk of downstream impact both during operations and post-closure.

Recommendations

Incorporation of the management measures for geochemical stability outlined in Chapter 4 into the mine plan results in a management strategy with extremely low residual risk of downstream impact both during operations and post-closure.

Key recommendations to refine the geochemical assessment of mine materials for the 5 Mile deposit prior to Project commencement are as follows:

- Additional static and kinetic geochemical testwork should be conducted to improve confidence in the geochemical assessment and management strategies.
- All waste rock intervals in drillholes intersecting the proposed mine pit and wall rock should be analysed for sulfur (by LECO method) and ANC. Note that the prevalence of ankerite in the materials indicates that ANC tests should be conducted with hydrogen peroxide addition.
- A geochemical classification layer should be developed for the mine block model in order to refine estimated volumes of materials in each management category, and to facilitate waste rock dump design and assessment of volumes of Category C waste rock for in-pit disposal.
- Column leach testwork is recommended to further characterise potential NMD drainage quality from the various rock categories.
- A detailed waste rock dump design should be developed.

1 Introduction

1.1 Background

Earth Systems was engaged by Eastern Iron Limited (EIL) to undertake a geochemical assessment of waste rock, wall rock and ore for the proposed Nowa Nowa Iron Project, eastern Victoria. This work forms part of an environmental assessment conducted as part of an EES Referral for the Project.

Eastern Iron, through its wholly owned subsidiary Gippsland Iron Pty Ltd, proposes to develop the 5 Mile magnetite/haematite deposit located approximately 7 km north-northeast of the town of Nowa Nowa in Victoria (Figure 1). The site is located in State Forest with a history of timber harvesting, and within the catchment of Boggy Creek and Lake Tyers, which is located approximately 15 km downstream of the proposed mine site (Figure 2).

Figure 1: Regional location of the proposed Nowa Nowa Iron Project (Engenium, 2012).

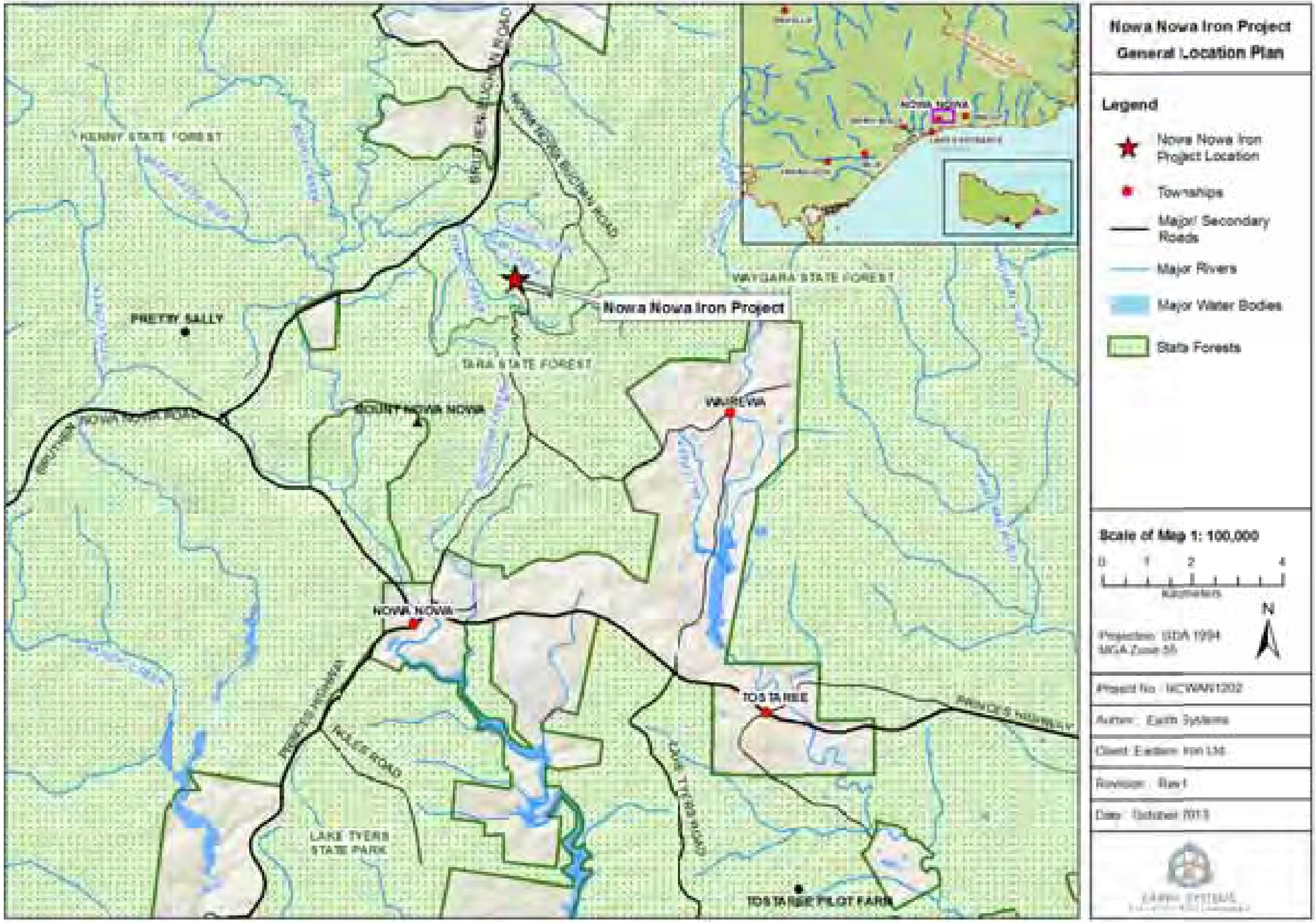

Figure 2: Location of the proposed mine site for the Nowa Nowa Iron Project.

The 5 Mile deposit was identified by a prominent magnetic anomaly and extensively drilled in the 1950s but has never been developed. The deposit consists of a massive magnetite/haematite ore body within Silurian felsic volcanics (Thorkidaan Volcanics), turbidites and limestone. The mineralisation appears to be skarn-style or carbonate replacement, generating largely strata-bound ore. The mineralisation is characterised by massive magnetite-haematite with some pyrite. Magnetite appears to be late stage replacing specular haematite, but where extensive weathering is apparent haematite occurs after magnetite.

The hangingwall lithologies are Silurian Thorkidaan Volcanics, consisting of andesites, rhyolites, felsic ignimbrites, volcaniclastics and volcanic breccias. Footwall lithologies include mudstones, shales, sandstones and some limestone. The magnetite mineralisation dips roughly to the south at an angle of approximately 20–30°.

The 5 Mile ore is to be processed on site by dry low intensity magnetic separation (LIMS). It is estimated that the 5 Mile deposit would produce 8 Mt of magnetite product, 2 Mt of low-grade ore, and ~20 Mt of waste rock over an operating term of 10 years. The proposed operation comprises an open pit, a processing plant, a waste rock dump, a low-grade ore stockpile, three water management storages, a temporary waste stockpile, site administration facilities and associated infrastructure.

1.2 Objectives

The objective of this study is to classify geological materials of the 5 Mile deposit according to geochemical characteristics and long-term stability, and to identify management strategies for each category of material in order to minimise any potential for water quality impacts associated with the proposed mining operations.

The scope of works for this study is as follows:

- Review available geological, mineralogical and geochemical data and information.
- Conduct a site assessment and identify key representative lithological units.
- Select geological samples representative of key lithologies and material categories (e.g. waste rock, ore and wall rock) considering factors such as spatial extent/distribution and oxidation state.
- Conduct static geochemical testwork on the selected samples and classify materials according to geochemical stability.
- Conduct kinetic geochemical testwork and mineralogical/chemical analyses on a selected set of representative geological samples to characterise the short- and long-term geochemical behaviour of these materials.
- Identify strategies for the management of each material classification in order to maximise the geochemical stability of mine materials and minimise any potential water quality risks associated with their disturbance as part of mining operations.

2 Method

2.1 Overview

The present investigation involved the following tasks:

- Review of data and site assessment;
- Geochemical assessment, involving:
  - Static geochemical characterisation and classification;
  - Kinetic geochemical characterisation;
- Development of strategies for the management of mine materials that can be incorporated into Mine Plans, Rehabilitation Strategies and Closure Plans.

These tasks are described in detail below.

2.2 Review of Data and Site Assessment

The following data were obtained from EIL over the course of the geochemical assessment and used where applicable in the study:

- Geological logs;
- Exploration drill collar locations;
- Assay data for exploration drillholes.

The following reports (see Table 1) relevant to the 5 Mile iron deposit were reviewed, and where relevant used where cited in this report.

Table 1: Existing reports relevant to the 5 Mile deposit.

Report	Year	Relevant Content
Bell, 1959. The Iron Ore Deposits of Nowa Nowa, Eastern Gippsland, Bulletins of the Geological Survey of Victoria, No. 57	1959	Geological drillhole logs (~33) Total iron and sulfur assays for 17 drillholes, 377 sample intervals Interpretive geological cross-sections
Mitchell Cotts Projects, 1986. Pre-feasibility Study for the Production of Direct Reduced Iron from the Nowa Nowa Iron Ore Deposits	1986	Limited resource estimation Major element analysis for 32 unlabelled samples One interpretive geological cross-section One geological drillhole log
Engenium, 2012. Nowa Nowa Project Scoping Study. Confidential report prepared for Eastern Iron Limited by Engenium Pty Ltd (14 Dec 2012).	2012	Dry LIMS metallurgical testwork results Interpretive geological cross-sections

Specifically, the sulfur and iron data reported in Bell (1959) permit assessment of the likely sulfide (pyrite equivalent) content of ore materials, and the dry LIMS metallurgical testwork results reported in Engenium (2012) permit estimation of likely compositions of LIMS product and reject low-grade ore materials.

Earth Systems geochemical specialists visited the proposed mine site in February 2013 to develop an understanding of the geology, mineralogy, preliminary mine plans and potential geochemical risks associated with the Project. The site visit included the following tasks:

- Discussions with the geologist regarding:
    - the exploration drilling program;
    - geology and mineralisation;
    - preliminary mine plans and pit shells;
    - sample selection for geochemical assessment;
    - availability of sample materials;
- Inspection of the 5 Mile site;
- Inspection of representative drill core;
- Geomorphology and receptor area assessment.

2.3 Geochemical Assessment

The geochemical assessment involved the following tasks:

- Sample Selection and Collection
- Static Geochemical Assessment
- Kinetic Geochemical Assessment

Details of the procedures and protocols for each task are provided in Annex A.

2.4 Development of management strategies for mine materials

Management strategies for the handling and long-term safe storage of mine materials during operation and post-closure were developed based on the geochemical assessment and the corresponding mine material classifications. These management strategies form an integral part of the Mine Plan and were developed to permit the site to transition easily to permanent, safe and geotechnically and geochemically stable closure.

3 Geochemical Assessment

3.1 Geological Characterisation

The Nowa Nowa Project is located in the Lachlan Orogen, which extends from eastern Tasmania through central and eastern Victoria into New South Wales and Queensland. The 5 Mile deposit consists of a massive magnetite/haematite ore body within Silurian felsic volcanics (Thorkidaan Volcanics), turbidites and limestone. The surface geology in the project area is shown in Figure 3.

The style of mineralisation appears to be skarn-style or carbonate replacement. The mineralisation is characterised by massive magnetite-haematite with some pyrite. Magnetite appears to be late stage replacing specular haematite, but where extensive weathering is apparent haematite appears to occur after magnetite.

The Thorkidaan Volcanics consist of andesites, rhyolites, felsic ignimbrites, volcaniclastics and volcanic breccias, and represent the dominant hangingwall lithology. Footwall lithologies include mudstones, shales, sandstones and some limestone. The magnetite mineralisation dips roughly to the south at an angle of approximately 20–30°.

An interpretive cross-section for the mineralised zone (Engenium, 2012) is shown in Figure 4. Note that the geology west of the fault remains to be finalised, and is preliminarily identified as volcaniclastics or other sediments of comparable lithology.

The key lithologies (and the corresponding lithology codes used in geological logs) identified for assessment and the corresponding mineralogy (as determined by XRD in this study) are listed in Table 2.

Table 2: Key lithologies and indicative mineralogy.

Lithology	Geological log codes	Indicative mineralogy
Volcanics	FVC, IVA	Albite (71%), chlorite (15%), biotite (6%), quartz (3%), muscovite (2%), hematite (2%), ankerite, serpentine, pyrite
Sediments	SSH, SSH(BK), SST	*Black shale:* Quartz (67%), muscovite (20%), chlorite (6%), biotite (2%), pyrite (2%), talc (2%), hematite, albite, ankerite
Limestone	SCL	*Not analysed*
Ore	MRH, MRM, FRH, FRM	*Wet LIMS tails:* Hematite, pyrite, chlorite, ilmenite, talc, quartz, biotite, serpentine, siderite, kaolinite (plus magnetite in ore)

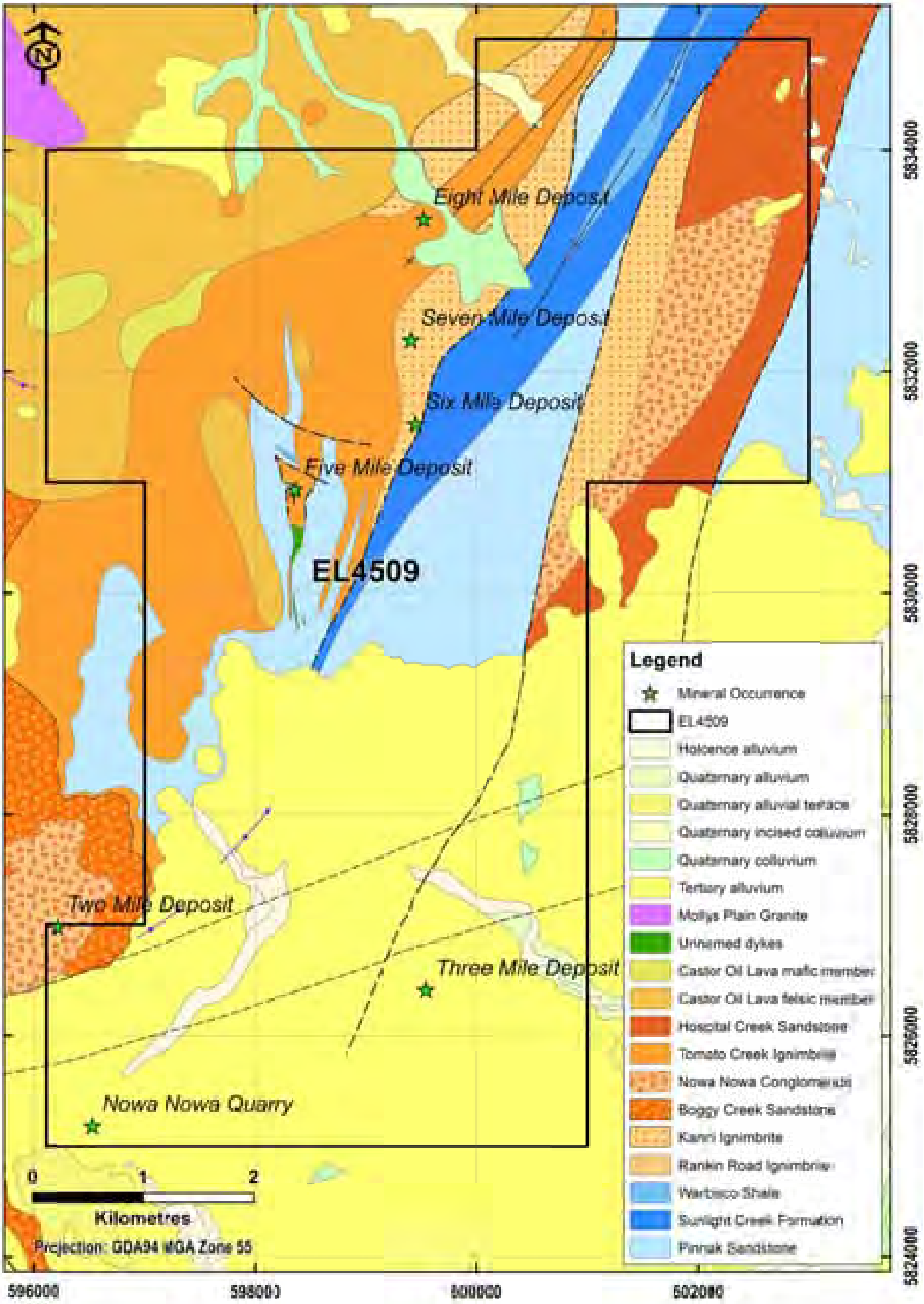

Figure 3: Regional geology, mineral occurrences and exploration lease area for the Nowa Nowa Iron Project (Engenium, 2012; excerpt from Geological Survey of Victoria, 1996).

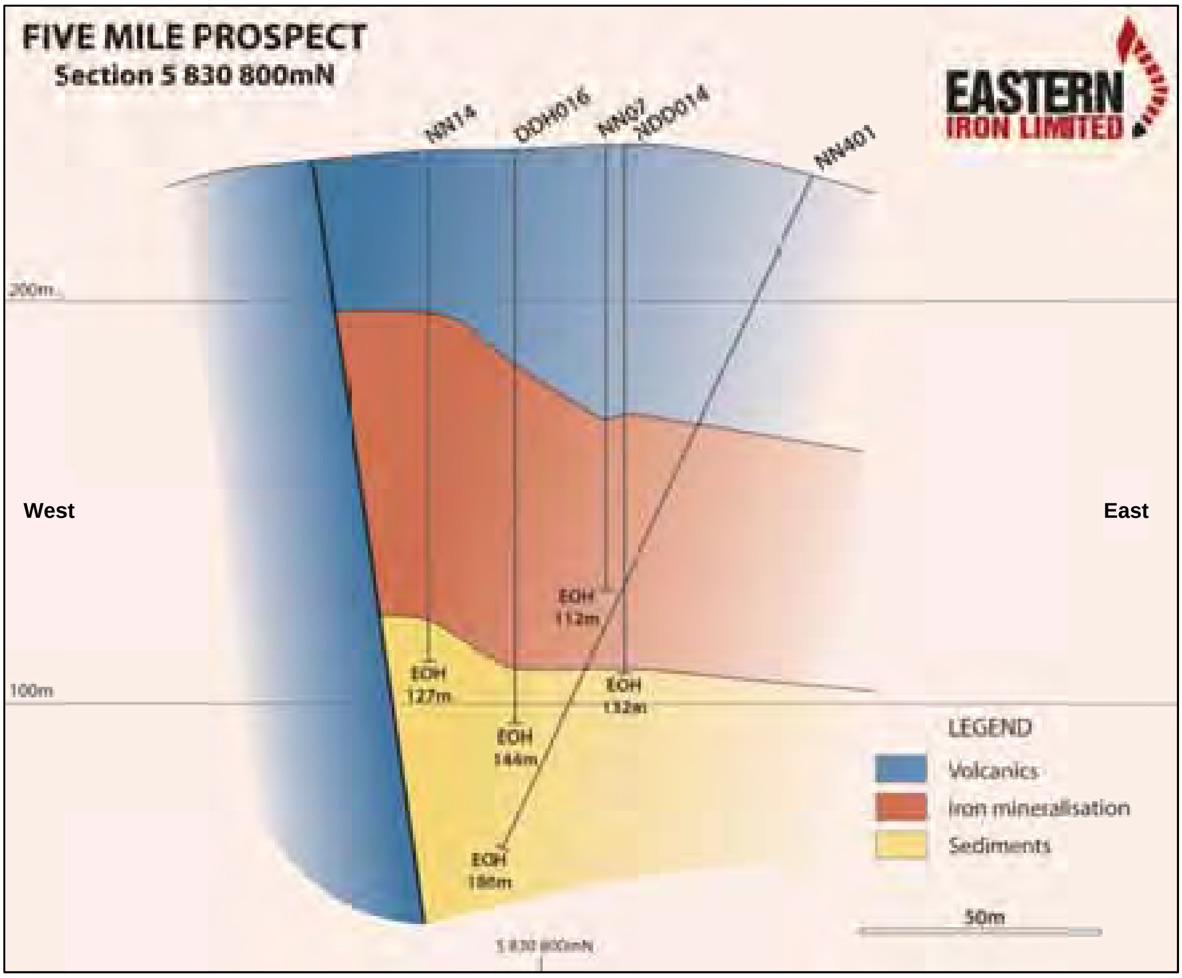

Figure 4: Interpretive cross-section for the 5 Mile deposit reported (Engenium, 2012).

3.2 Mining and Processing

The 5 Mile operation is intended to be a conventional open cut mine with ore processed by dry LIMS on –10 mm crushed material. Based on metallurgical testing, this dry LIMS processing will produce a product stream representing approximately 80% of total ore, and a low-grade ore stream representing the remaining 20% of total ore. The separated product is to be temporarily stockpiled at site and then trucked to port (Eden, NSW; see Figure 1) for shipping. The low-grade reject stream will be stockpiled at the mine site during mine operations for potential reprocessing and sale.

A summary of the indicative tonnages of the various mine materials expected to be produced by the mining operation is provided in Table 3.

Table 3: Summary of tonnages of mine materials.

Material	Estimated tonnage over life of mine (Mt)
Waste rock	24
Ore (total)	10
– Shipped product	(8)
– Low-grade stockpile	(2)
Total	34

3.3 Geochemical Classification

Exposure of sulfidic materials to atmospheric oxygen can result in the generation and release of salinity, dissolved metals and/or acid. Understanding the nature and distribution of reactive minerals within mine materials is important for identifying potential water quality issues during operations and post closure.

Assessment and classification of mine materials on the basis of geochemical stability allows specific management strategies to be developed for materials with different geochemical profiles in order to ensure safe handling and storage in the long term. The key factors on which geochemical stability is determined are as follows:

- Saline drainage potential;
- Neutral metalliferous drainage (NMD) potential;
- Acid and metalliferous drainage (AMD) potential.

Refer to Annex A for the full geochemical assessment and derivation of the geochemical classification scheme presented in the following sections.

Geochemical assessment and classification was performed for all geological materials to be handled or disturbed by the mining operations. These materials are as follows:

- Waste rock
- Ore and product
    - ROM ore
    - Dry LIMS product (–10 mm)
    - Low-grade ore (–10 mm)
- Wall rock

The classification schemes for each of these materials are described below.

3.3.1 Waste Rock

A geochemical classification scheme for waste rock was developed on the basis of the following:

- Static geochemical analysis of 37 representative waste rock samples selected from five drillholes for which geological logs were available;

- Kinetic geochemical analysis of two waste rock samples of representative lithologies (volcanics and black shale);
- Simulated kinetic geochemistry (including pyrite oxidation rate, acidity generation rate, and lag time to onset of acid conditions) for average compositions of key waste rock lithologies.

The geochemical classification scheme and management categories thus developed are described in Table 4.

Table 4: Geochemical classification of waste rock materials according to management category for the 5 Mile deposit.

Management category	Geochemical classification criteria	Geochemical properties		
		AMD potential	NMD potential	Salinity potential
Category N	NAPP < –40 kg H_2SO_4/t AND Sulfur < 0.6 wt%	Potentially acid consuming	Very low potential for NMD generation	Very low potential for salinity generation
Category A	NAPP < 0 kg H_2SO_4/t AND Sulfur < 0.3 wt%	Non acid forming (NAF)	Very low potential for NMD generation	Very low potential for salinity generation
Category B	NAPP < +10 kg H_2SO_4/t AND Sulfur > 0.3 wt% AND < 0.6 wt%	Potentially acid forming (PAF) – marginal	Low potential for NMD generation	Low potential for salinity generation
Category C	NAPP > +10 kg H_2SO_4/t OR Sulfur > 0.6 wt%	Potentially acid forming (PAF)	Moderate potential for NMD generation	Moderate potential for salinity generation

The estimated abundance of each management category by waste rock lithology based on the present limited assessment of 37 waste rock intervals is provided in Table 5, and the estimated overall mass of waste rock predicted to fall into each management category are provided in Table 6.

Table 5: Estimated abundance of each management category by waste rock lithology.

Management category	Waste rock lithology		
	Volcanics	Sediments	Limestone
	%	%	%
Category N	0	8	50
Category A	91	42	50
Category B	9	25	0
Category C	0	25	0

Table 6: Estimated mass of waste rock by management category.

Waste rock lithology	Estimated proportion of total waste rock* (%)	Mass of waste rock by management category (Mt)			
		A	B	C	N
Volcanics	70	15.3	1.5	0.0	0.0
Sediments	20	2.0 1.2 1.2 0.4			
Limestone	10	1.2	0.0	0.0	1.2
Total	100	18.5	2.7	1.2	1.6

*Preliminary estimate based on interval metres in sighted geological logs and interpretive cross-sections.

Note that the management categories (Table 4) are based on management requirements for rocks of given geochemical properties, and are not based on the precise abundances of each category of materials.

The management categories in Table 4 are to be used in conjunction with the mine block model by construction of a geochemical classification layer using the classification criteria. This would involve the following:

- Analysis of all waste rock intervals in resource drillholes for:
  - Total sulfur (by LECO)
  - Acid neutralisation capacity (ANC)
- Calculation of maximum potential acidity (MPA) from total sulfur:
  - MPA [kg H_2SO_4/tonne] = Sulfur [wt%] × 30.6
- Calculation of net acid producing potential (NAPP) from MPA and ANC:
  - NAPP [kg H_2SO_4/tonne] = MPA [kg H_2SO_4/tonne] – ANC [kg H_2SO_4/tonne]
- Application of the criteria in Table 4 to assign a management category to every waste rock block in the mine model;

The geochemical classification layer thus constructed should then be used to schedule waste materials for selective management as described in Section 4.

3.3.2 Ore

A geochemical classification scheme for ore materials was developed on the basis of the following:

- Static geochemical analysis of 10 ore samples selected from five drillholes for which geological logs were available;
- Statistical analysis of total sulfur data for 377 historical ore intervals from Bell (1959);
- Mass separation, total sulfur and iron data for preliminary dry LIMS metallurgical testwork from Engenium (2012);
- Kinetic geochemical analysis of a wet LIMS tail sample from early metallurgical testing;
- Simulated kinetic geochemistry (including pyrite oxidation rate, acidity generation rate, and lag time to onset of acid conditions) for average compositions of each ore category.

The geochemical classification scheme and management categories thus developed for ore materials are described in Table 7.

Table 7: Geochemical classification of ore materials according to management category for the 5 Mile deposit.

Management category	Geochemical properties		
	AMD potential	**NMD potential**	**Salinity potential**
ROM ore	Potentially acid forming (PAF) Average NAPP: +44 kg H_2SO_4/t Average estimated lag time to onset of acid conditions: 2 years	High initial potential for NMD generation	High potential for salinity generation
Dry LIMS product	Potentially acid forming (PAF) Average NAPP: +27 kg H_2SO_4/t Average estimated lag time to onset of acid conditions: 3 years	Moderate initial potential for NMD generation	Moderate potential for salinity generation
Low-grade ore	Potentially acid forming (PAF) Average NAPP: +107 kg H_2SO_4/t Average estimated lag time to onset of acid conditions: 1 year	High initial potential for NMD generation	High potential for salinity generation

Note that the processed ore streams have a grain size of –10 mm. Dust generation from these materials will need to be managed throughout operations.

3.3.3 Wall Rock

Wall rock will approximately comprise the main waste rock lithologies in the proportions listed in Table 6. A relatively small amount of unmined ore (equivalent to ROM ore) may also be present in the eastern, northern and/or southern pit walls at the end of mine life.

4 Management of Mine Materials

4.1 Management Principles

The disturbance of geological materials by mining activities exposes sulfidic materials to oxygen and weathering processes. The key principles affecting the geochemical stability of geological materials are as follows:

- Prior to disturbance, geological materials would have been geochemically stable, either saturated with groundwater, or if unsaturated having already undergone oxidation and weathering over geological timescales.
- Dewatering of previously saturated geological materials permits oxidation and decomposition of sulfidic materials, potentially producing acid (in the form of sulfuric acid) and releasing soluble metals (such as iron and aluminium). Such oxidation processes have the potential to continue for extended periods (up to 100s to 1,000s of years) depending on rock properties.
- Sulfide minerals (primarily pyrite) are inherently geochemically unstable when exposed to atmospheric oxygen.
- Existing acid sulfate weathering products in the dewatered profile can undergo accelerated dissolution on increased exposure to water.

The management of mine materials aims to maximise geochemical stability so as to minimise the potential for water quality impacts during operations and post-closure. The key principles of management for geochemical stability are as follows:

- Wherever possible, sulfidic materials should be properly stored under a permanent water cover (minimum 2 m) to prevent oxidation.
- Where surface storage of potentially geochemically unstable materials cannot be avoided, rock dumps should be constructed so as to minimise the ingress of oxygen and water and thereby minimise the rate of oxidation and the flux of acid sulfate related acidity.
- All drainage potentially affected by sulfide oxidation should be captured and treated so as to prevent the discharge of water that does not meet environmental objectives for the site.
- Care should be taken to ensure that acid sulfates, if present, are accounted for in material management.

The application of these management principles in mine planning is described in Section 4.2.

4.2 Integration of Management Principles into Mine Planning, Rehabilitation and Closure

The proposed mine plan integrates the management principles described in Section 4.1. The mine layout, which incorporates these principles, is shown in Figure 5. This Mine Plan and project arrangement have been developed to permit mining in a manner that facilitates the transition to closure and beyond.

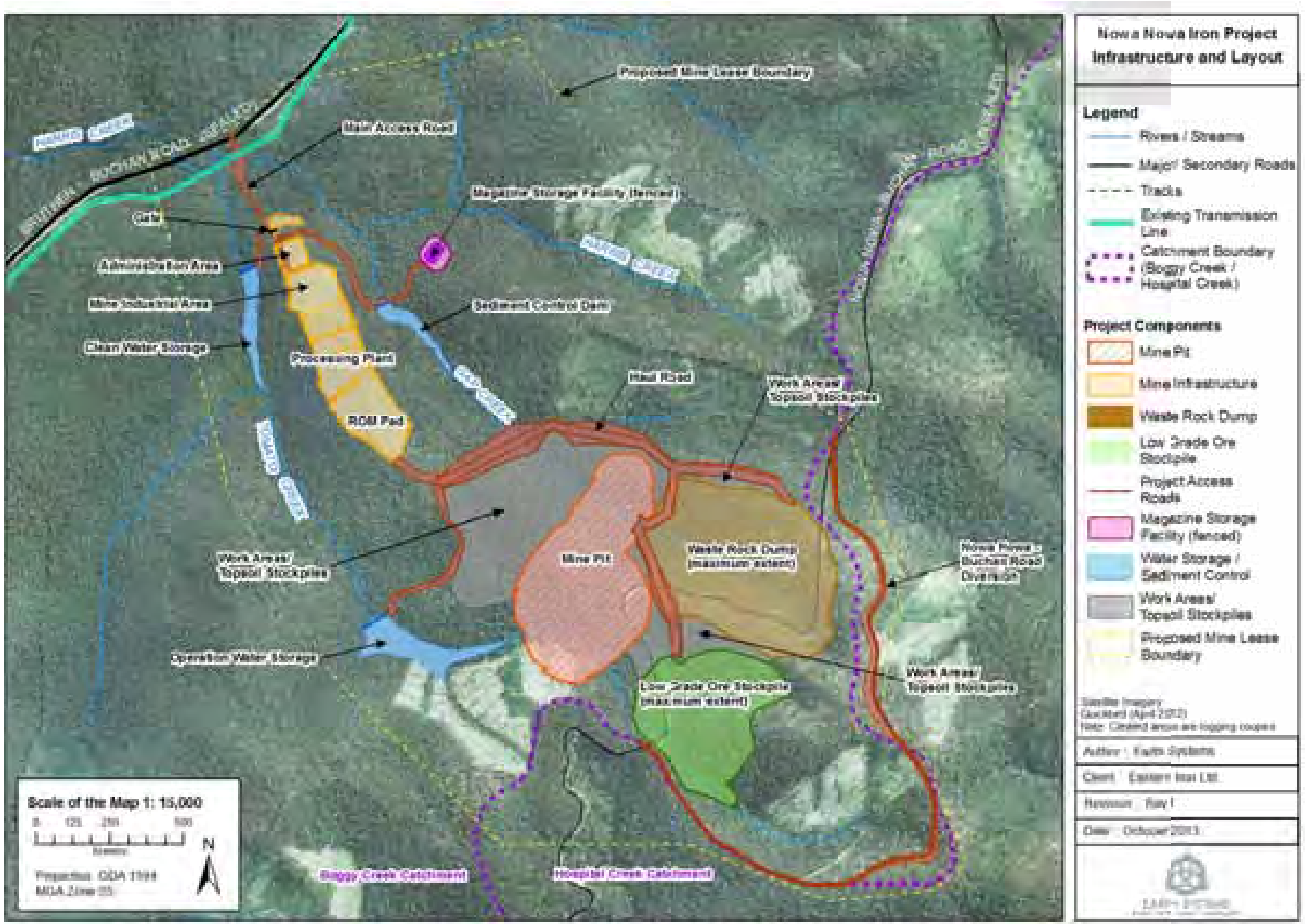

Figure 5: Proposed project arrangement.

Features of the mine plan to note with regard to management of geochemical stability are as follows:

- There is no tailings storage facility (TSF).
- The mine pit is designed to flood on mine closure, and to overflow into Tomato Creek.
- Sulfidic materials (Category C waste rock and unsold low-grade ore), are to be backfilled into the open pit on mine closure for storage under a permanent water cover (minimum 2 m) to prevent oxidation, and during operations are to be temporarily stockpiled in a location upstream of the pit to ensure that any drainage ultimately reports to the pit.
- Category A, B and N waste rock materials are to be stored permanently in a waste rock dump located upstream of the pit in Gap Creek. This location ensures that any drainage from the waste rock dump ultimately reports to the open pit both during operations and post-closure.
- The waste rock dump is to be constructed such that Category B materials are encapsulated within Category A and N materials to inhibit sulfide oxidation and potential release of acid drainage in the long term.
- An Operations Water Storage is to be located immediately downstream of the pit on Tomato Creek to capture all drainage from the pit, waste rock dump, ROM pad and stockyard, and the temporary low-grade ore stockpile and Category C waste rock pile during operations. The storage and its management are designed for zero discharge downstream.
- Additional water storages downstream (Clean Water Storage, Sediment Control Dam) will provide additional protection to prevent any potential residual downstream water quality impacts.
- Drainage from all other mine infrastructure is to report to the Sediment Control Dam during operations.
- Post-closure, the pit is to be flooded after placement of sulfidic materials. To minimise the period that sulfidic materials and wall rock will be exposed to atmospheric oxygen, natural inflows from the upstream catchment and groundwater rebound are to be augmented by pumping clean catchment water from the Clean Water Storage and Sediment Control Dam.
- To maximise the amount of runoff reporting to the open pit post-closure, the waste rock dump is to be completed with a cover system using suitable waste rock and clay materials to minimise the infiltration of water into the dump and maximise runoff generation. The area of the top surface of the dump is to be maximised and graded to the east to allow all runoff to be captured at the upstream end of Gap Creek and diverted into the adjacent Tomato Creek catchment (using the new topography).

The management strategies to be implemented for each management category of mine materials are summarised in Table 8.

Table 8: Summary of management strategies for categorised mine materials.

Management category	Management strategy
Waste rock category A	Waste rock dump in upper Gap Creek
Waste rock category B	Waste rock dump in upper Gap Creek, encapsulated within Category A and N waste rock
Waste rock category C	Temporarily stockpile upstream of the open pit in Tomato Creek with drainage control, and on closure storage in the open pit under a permanent water cover (min. 2 m)
Waste rock category N	Waste rock dump in upper Gap Creek and/or storage in the open pit on closure for pit water treatment
Low-grade ore	Temporarily stockpile upstream of the open pit in Tomato Creek with drainage control, and on closure storage in the open pit under a permanent water cover (min. 2 m)

4.3 Specific Management Strategies

Specific management strategies were developed for each of the key potential AMD domains:

- Waste rock
- Ore
- Wall rock
- Pit lake

The management strategies for each domain are described below. These strategies have been developed using the limited data available. More detailed geochemical characterisation of waste rock, wall rock and the mining schedule will be required to confirm and refine these strategies.

4.3.1 Waste Rock

Specific management measures for the various management categories of waste rock are as follows:

Operations

- A waste rock dump containing only Category A, B and N waste rock materials is to be constructed upstream of the open pit in Gap Creek (see Figure 3).
- To maximise the long-term geochemical stability of the waste rock dump, it is to be constructed in thin horizontal lifts from the base of the dump upward, with compaction and moisture content optimised to minimise air entry. This involves truck dumping with subsequent flattening and compaction (with optimum moisture content) of each layer (1–2 m) prior to placement of the next layer on top. Traditional end-dumping construction methods are to be avoided, as such methods are well known to produce internal dump structures that enhance sulfide oxidation and pollution discharge.
- Category B waste rock should be encapsulated within Category A and N materials by strategic placement so as to avoid positioning the Category B materials close to the edge of the dump. A minimum 10 m buffer of Category A/N materials should be placed between the dump edges and the Category B material. This encapsulation approach isolates the Category B material in engineered cells to minimise oxygen and water infiltration.

- Category N materials, with excess neutralising capacity should be placed strategically to optimise in situ neutralisation. The acid-neutralising layers can be located so as to intercept and neutralise seepage.
- Category C waste rock is to be temporarily stockpiled upstream of the open pit in Tomato Creek (see Figure 3) as a retention structure for the low-grade ore stockpile (see Section 4.3.2).
- Each lift of the waste rock dump is to be compacted and graded such that all drainage is directed eastward (upstream) into the Gap Creek and contained in a pond/sump for pumping to the Operations Water Storage for treatment (if necessary) and reuse in ore processing and dust suppression.
- In the event that runoff exceeds pumping capacity, excess drainage from the waste rock dump will report to the open pit.
- More detailed geochemical characterisation of the waste rock and the mining schedule will be required to develop a more detailed designed for the waste rock dump.

Post Closure

- The waste rock dump is to be completed with a cover system that minimises the infiltration of water into the dump and maximises runoff generation. This cover system will require an impermeable layer (such as clay) to prevent infiltration and an overlying armour layer (coarse rock) to prevent erosion. Basal clays from the water storages will be available as impermeable materials for the dump cover system once the storages are decommissioned.
- The area of the top surface of the dump is to be maximised and graded to the east to allow all runoff to be captured at the upstream end of Gap Creek and diverted into the adjacent Tomato Creek catchment (using the new topography). The surface should be gently sloping and channelled to maximise runoff capture and minimise erosion.
- Clean catchment water collected from the waste rock dump is to be channelled around the top of dump into the adjacent Tomato Creek catchment to ultimately report to the open pit.
- Drainage from the waste rock dump will report to the pit post-closure for passive treatment. The chemistry of leachate from the waste rock dump is to be monitored throughout operations to confirm any potential requirement for additional treatment.
- Category C waste rock should be backfilled into the open pit on closure for storage under a permanent water cover (minimum 2 m) to prevent sulfide oxidation. Backfilling should be conducted such that no waste rock will become perched on pit benches above the height of the final waste rock pile.

4.3.2 Low-Grade Ore

Specific management measures for the low-grade ore stockpile are as follows:

Operations

- Low-grade ore is to be temporarily stockpiled upstream of the open pit in Tomato Creek (see Figure 3).
- Category C waste rock (or other waste rock if Cat. C is not available) should be used to construct a retention structure to contain the low-grade ore and prevent erosion and/or uncontrolled runoff from the stockpile.
- Drainage from the stockpile is to be captured in a sump and pumped to the Operations Water Storage for treatment (if necessary) and reuse in ore processing and dust suppression.

- In the event that runoff inflows exceed pumping capacity, excess runoff from the stockpile will report to the open pit.
- If feasible, the northern extent of the open pit could be developed first and the low-grade ore backfilled into the completed northern pit during operations to minimise the potential for AMD generation and dust generation during operations, while ensuring the low-grade ore remains accessible for reprocessing or shipping.
- The geochemistry of the low-grade ore and the chemistry of drainage from the stockpile should be monitored throughout operations to confirm potential treatment requirements.
- Treatment of drainage from the low-grade ore stockpile, if required, could involve the application of a suitable acid-neutralising agent (eg. calcium hydroxide) using a small portable dosing system.

Post Closure

- On mine closure, all of the low-grade ore (if unsold or unfit for reprocessing) should be backfilled into the open pit for storage under a permanent water cover (minimum 2 m) to prevent sulfide oxidation.
- The low-grade ore material is predicted to be acid producing but to have a lag time of approximately 1 year to the onset of acid conditions. The material in the low-grade ore stockpile is therefore expected to be net acidic at the time of mine closure. The geochemistry of the low-grade ore stockpile will need to be assessed at mine closure to determine whether any addition of acid-neutralising material is needed for backfilling into the pit.

4.3.3 ROM Ore and LIMS Product

ROM ore and the LIMS product both require specific management measures during temporary stockpiling to avoid the release of salinity, near-neutral metalliferous drainage or AMD, as follows:

- The ROM ore is predicted to be acid producing but to have a lag time of approximately 2 years to the onset of acid conditions (see Annex A). ROM ore should therefore not be stockpiled under unsaturated conditions for more than ~2 years.
- Drainage from the ROM pad has the potential to present with elevated levels of sulfate and dissolved metals. Drainage from the ROM pad is to be contained and transferred to the Operations Water Storage for treatment (if necessary) and reuse in ore processing and dust suppression.
- The LIMS product is predicted to be acid producing but to have a lag time of approximately 3 years to the onset of acid conditions (see Annex A). The LIMS product should therefore not be stockpiled under unsaturated conditions for more than ~3 years.
- Drainage from the LIMS product stockpile has the potential to present with elevated levels of sulfate and dissolved metals. Drainage from the stockpiled product is to be contained and treated if necessary.

4.3.4 Wall Rock

Specific management measures for pit wall rock are as follows:

Operations

- Drainage from wall rock into the open pit during operations may present with elevated salinity, dissolved metals, and/or acidity due to the potential oxidation of sulfides and/or the dissolution of acid sulfate salts. All drainage accumulated in the open pit is to be pumped to the Operations Water Storage for treatment (if necessary) and reuse in ore processing and dust suppression.

Post Closure

A preliminary model of the mine pit showing the post-closure water level is provided in Figure 6, and an interpretive geological section showing the likely lithological exposure in the highwalls on closure is shown in Figure 7.

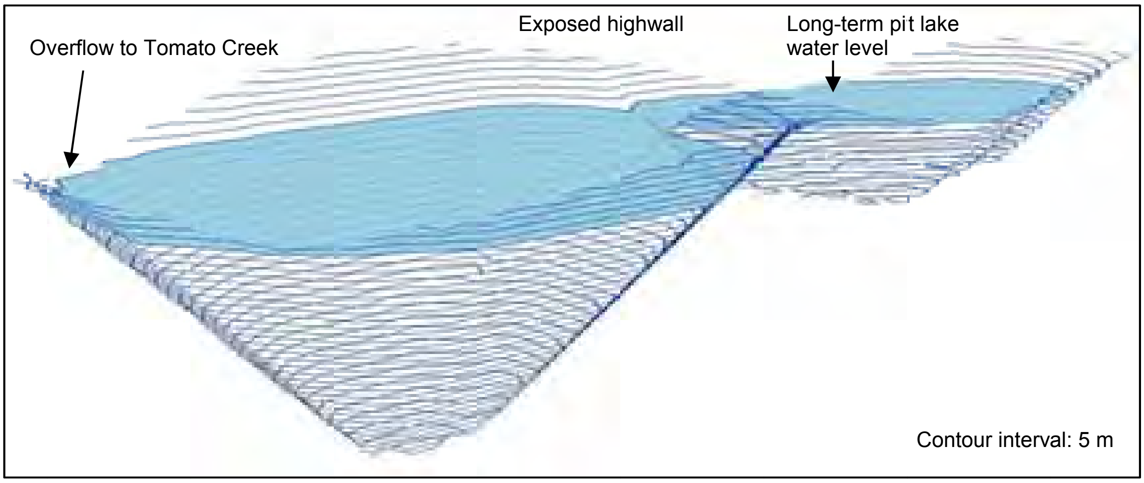

Figure 6: Preliminary pit shell showing design long-term flood level (approx. 190 mAHD).

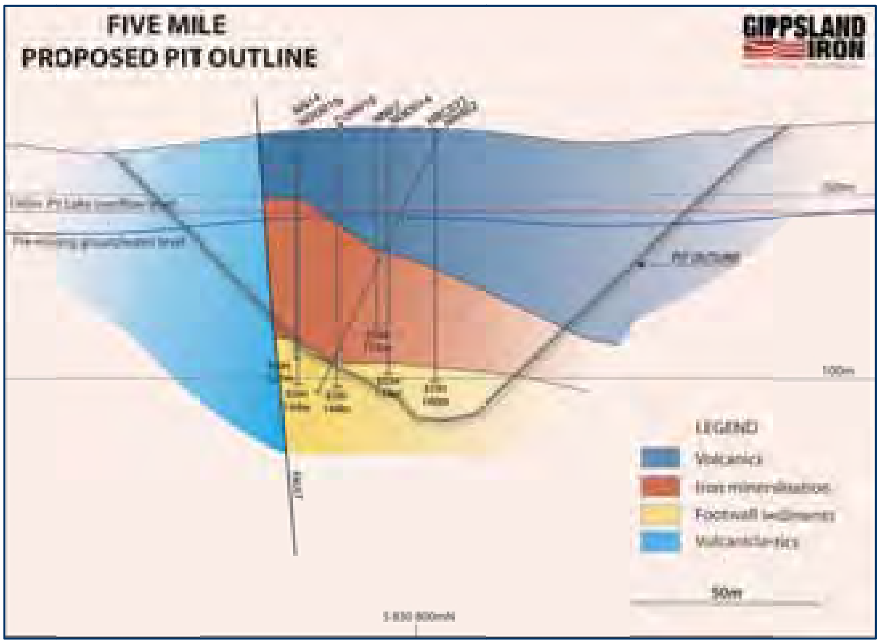

Figure 7: Preliminary geological section showing the highwall lithologies, long-term flood level and estimated pre-mining groundwater level.

- Post-closure, the open pit is designed to flood and overflow regularly into Tomato Creek. The overflow level of the pit lake is approximately 190 mAHD, and the premining peak groundwater level in the pit area is approximately 187 mAHD. The post-closure flood level of the pit is therefore designed to be marginally higher than the premining groundwater level.
- The pit lake is designed to provide passive treatment for all inflows through a combination of retention time, sulfate reduction by sulfate reducing bacteria (SRB), and acid neutralisation by alkalinity produced by SRB activity and the dissolution of limestone, and alkalinity brought in by groundwater.
- The post-closure pit will have highwalls of 30–40 m in height (above the pit lake water level) on the western and eastern sides exposing volcanics (see Figure 6 and Figure 7). Note that all of the exposed wall rock on closure was previously above the groundwater level (and hence exposed to oxidation over geological time). Exposure as wall rock will therefore not appreciably alter the geochemical environment of those rocks.
- Some relatively minor sulfide oxidation is expected from the exposed highwalls in the long term, but geochemical assessment shows that no acid drainage will be produced (see Annex A). Based on observations from historical quarries in the area, this oxidation only appears to occur on rock surfaces and is expected to be limited. All drainage from the exposed highwalls reports to the pit for passive treatment.
- As the pit is flooded, any acidity or salinity generated in the groundwater drawdown cone during operations will be flushed into the pit. The chemistry of pit lake water should be monitored throughout the flooding operation to identify whether treatment (eg addition of limestone or calcium hydroxide) may be required in this initial flood period.
- To minimise the period that wall rock is exposed to atmospheric oxygen on closure and to dilute potentially saline water, flooding of the pit should be augmented by pumping from the Clean Water Storage and Sediment Control Dam (in addition to natural inflows from groundwater and upstream runoff).

4.3.5 Mine Pit Lake and Mine Water Storages

Specific management measures for the mine pit lake and mine water storages post-closure are as follows:

- The post-closure water balance indicates that the pit lake will overflow regularly into Tomato Creek in the long term (see *Attachment 5 - Surface and Groundwater Study*).
- Backfilling of Category C waste rock and low-grade ore (if any remains) into the pit is to be conducted in a manner that prevents the backfilled materials from becoming perched on benches above the height of the final waste rock pile. Perched material may not remain permanently under water and has the potential to present a long-term water quality risk.
- An extended period of low water level in the pit post-closure (ie due to slow rate of flooding) may permit sulfide oxidation to proceed in backfill and wall rock materials, resulting in the accumulation of acidity in the pit lake. This situation should be prevented as far as practicable.
- The pit is to be flooded as quickly as practicable on mine closure. In addition to the inflow of catchment drainage and groundwater, clean water from the Clean Water Storage and Sediment Control Dam should be pumped into the pit to ensure that the pit fills in the shortest practical timeframe.

- A layer of acid-consuming materials (eg. Category N waste rock) and organic material should be laid over the backfilled materials in order to promote the activity of sulfate-reducing bacteria in the base of the pit lake. This will assist in minimising levels of sulfate salinity and any metals in the pit lake over the long term.
- The rim of the mine pit and the upstream catchments should be revegetated in order to ensure a long-term supply of organic matter in into the pit lake.
- Drainage from the catchments upstream of the pit should be maximised and kept clean.
- The Operations Water Storage is to be decommissioned on closure but the structure retained as a wetland to passively treat overflow from the pit lake.
- The Clean Water Storage downstream of the operations dam should similarly be decommissioned but the structure retained as an additional wetland to polish water draining from the decommissioned Operations Water Storage.
- The Sediment Control Dam is to be decommissioned on mine closure and the former channel reinstated if no alternative use for the dam is identified.

5 Recommendations

Incorporation of the management measures for geochemical stability outlined in Chapter 4 into the mine plan results in a management strategy with extremely low residual risk of downstream impact both during operations and post-closure.

Key recommendations to refine the geochemical assessment of mine materials for the 5 Mile deposit prior to Project commencement are as follows:

- Additional static and kinetic geochemical testwork should be conducted to improve confidence in the geochemical assessment and management strategies.
- All waste rock intervals in drillholes intersecting the proposed mine pit and wall rock should be analysed for sulfur (by LECO method) and ANC. Note that the prevalence of ankerite in the materials indicates that ANC tests should be conducted with hydrogen peroxide addition.
- A geochemical classification layer should be developed for the mine block model in order to refine estimated volumes of materials in each management category, and to facilitate waste rock dump design and assessment of volumes of Category C waste rock for in-pit disposal.
- Column leach testwork is recommended to further characterise potential NMD drainage quality from the various rock categories.
- A detailed waste rock dump design should be developed.

6 References

Bell (1959). The Iron Ore Deposits of Nowa Nowa, Eastern Gippsland, Bulletins of the Geological Survey of Victoria, No. 57.

Engenium (2012), Nowa Nowa Project Scoping Study. Confidential report prepared for Eastern Iron Limited by Engenium Pty Ltd (14 Dec 2012).

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Annex A

Geochemical Assessment

Contents

A1 Introduction

Assessment of the geochemical properties and behaviour of waste rock, ore and pit wall rock is an important component of environmental impact assessment, providing information on the likely operational and post-closure environmental impacts of exposed mine materials.

Exposure of sulfidic geologic materials to atmospheric oxygen can result in the generation and release of acid. Natural carbonate minerals within the waste can partially or completely mitigate the acid generation process. Understanding the nature and distribution of reactive minerals within mine materials is important for identifying the potential for acid, metalliferrous and/or saline drainage from the geologic materials. Assessment of the geochemical properties of waste rock, ore and pit wall rock permits classification of the geochemical risk posed by these various disturbed site materials, and this in turn clarifies the need and likely success of various management strategies. Effective management strategies can only be developed once the likely geochemical behaviour of various materials has been established through static and kinetic geochemical testwork.

A description of the general processes relating to generation of acid and metalliferous drainage (AMD) is provided in Annex B.

A2 Method

A2.1 Sample Selection and Collection

The selection of representative geological samples is fundamental to achieving a representative geochemical assessment, and careful consideration is given at this stage to ensure that a suitable set of samples is collected for analysis.

Sample selection was limited to drillholes for which geological logs were available at the time of assessment (see Table A1).

Table A1: Drillhole logs available at the time of sample selection.

Hole ID	UTM East	UTM North	Relative Level	Depth	Inclination
	m	m	mAHD	mBGL	deg.
NDD015	598335	5830850	240	143.5	-90
NDD016	598325	5830800	238	143.5	-90
NDD017	598350	5830825	240	122.5	-90
NDD019	598375	5830905	235	96.8	-90
NDD020	598390	5830925	225	83.1	-90

Sample intervals of 2 m were selected for static geochemical analysis considering the following:

- The relative abundances of each non-ore lithology;
- The range of weathering states;
- The availability of material in intervals matching the block interval used at the prospect (2 m intervals, defined from ground surface);
- The three-dimensional spatial distribution of geological materials.

It assumed that these drillholes and the corresponding geological materials are representative of the entire deposit.

A total of 47 representative intervals of waste rock and ore were selected for static geochemical analysis. Two of these waste rock intervals were submitted for kinetic geochemical analysis. A sample of wet LIMS tailings from metallurgical testwork was also submitted for static and kinetic geochemical analysis.

Samples were selected by Earth Systems and collected as full drill core or as stored pulps (where available) by EIL.

Where existing pulps were available (eg. for most ore intervals), these were submitted for analysis using the appropriate laboratory ID for the pulp sample.

For remaining intervals (where pulps are not available), half cores were collected and prepared by EIL in intervals of 2 m (for static assessment only) or 4 m (for static and kinetic assessment), and despatched for analysis by ALS laboratories.

The samples to be submitted for kinetic geochemical testwork were prepared by ALS as follows: Samples were coarsely crushed to a nominal size of –15 mm (not smaller), split to recover a ~5 kg subsample, and then forwarded to Earth Systems for kinetic geochemical testing.

The full list of selected samples is provided in Annex D.

A2.2 Static Geochemical Characterisation

Standard static acid–base accounting (ABA), sulfur speciation and net acid generation (NAG) testwork is a core component of a geochemical assessment and allows the AMD and salinity risk profile of the various geological materials to be determined.

Static geochemical testwork was conducted by ALS Australia (a NATA accredited laboratory). Industry-standard static geochemical testwork procedures were used based on methods outlined in the AMIRA P387A Project ARD Test Handbook (2002) and Ahern et al. (2004). A list of the analytical and calculated parameters is provided in Table A2, and a description of the corresponding analytical methods is provided in Annex C. Tabulated analytical data is provided in Annex D, and the original laboratory reports for the present analyses are provided in Annex G.

Table A2: Analytical and calculated parameters for static geochemical testwork.

Parameter	Symbol/ Analyte	Limit of Reporting
Sulfur (total)	wt% S	0.01
Chromium-reducible sulfur (S_{Cr})	wt% S	0.01
Maximum potential acidity (MPA)	kg H_2SO_4/t	0.1
Acid neutralisation capacity (ANC)	kg H_2SO_4/t	0.1
Net acid producing potential (NAPP)	kg H_2SO_4/t	0.1
Net acid generation pH (NAG_{pH})	pH	0.1
Net acid generation to pH 4.5 ($NAG_{4.5}$)	kg H_2SO_4/t	0.1
Net acid generation to pH 7.0 ($NAG_{7.0}$)	kg H_2SO_4/t	0.1
KCl pH (pH_{KCl})	pH	0.1
KCl-extractable sulfur (S_{KCl})	wt% S	0.02
HCl-extractable sulfur (S_{HCl})	wt% S	0.02
Net acid-soluble sulfur (S_{NAS})	wt% S	0.02
Total actual acidity (TAA)	mole H^+/t	2

A2.3 Kinetic Geochemical Characterisation

Kinetic geochemical testwork assesses the decomposition rate of key acid-generating sulfide minerals within a sample. This is measured as the pyrite equivalent oxidation rate (POR) of a sample. Various sample characteristics that influence the POR, including sulfide mineralogy, particle size distribution and moisture content. Based on the POR, annual AMD generation, lag time before AMD generation, and indicative longevity of AMD generation can be determined. A description of the analytical methods available for kinetic geochemical characterisation is provided in Annex E.

The POR is expressed as a weight percentage of pyrite oxidised per year (i e. wt% FeS_2/year). Other commonly used intrinsic oxidation rate units include kilograms of oxygen consumed per kilogram of material per second (kg O_2/kg/s) or kilograms of sulfur oxidised per kilogram of material per year (kg S/kg/year). Expressing the POR in units of wt% FeS_2/year, normalised to the samples sulfide content, allows comparison of results between samples with different sulfide contents and also allows simple application of the results to estimate annual acidity generation rates for representative rocks with differing sulfide contents.

The POR for key waste rock lithologies was measured to:

- Estimate AMD/salinity generation rates;
- Provide the basis for estimating site-scale annual acidity/salinity generation rates;
- Inform the development of appropriate AMD/salinity management strategies on site.

A total of 3 rock samples were submitted to Earth Systems by EIL for kinetic geochemical characterisation. The table also lists the as-received gravimetric moisture content (wt% H_2O).

The moisture content (as received) of each sample was determined by the standard method (drying for 24 h at 105 °C).

Testwork method

Pyrite oxidation rates were determined by oxidation testing using the OxCon (oxygen consumption) method. The OxCon method allows oxidation rate results to be obtained quickly and accurately. Details of the OxCon method are provided in Annex F. Briefly, the method involves placing the sample in an OxCon apparatus and measuring the change in oxygen and carbon dioxide concentrations in head space gas over time.

Data assessment

Total sulfur and POR data were used to calculate the annual pollution generation potential for each sample, expressed as kilograms of sulfuric acid generated per tonne of material per year (kg H_2SO_4/t/year). The indicative lag time (if any) for the onset of acidification was calculated based on ANC results and the POR.

Solids characterisation

The test solids were subject to detailed geochemical characterisation by analysis of static geochemical parameters (as listed in Table A2), the acid-buffering characteristic curve (ABCC), comprehensive multi-element chemistry (as listed in Table A3) and mineralogy by semiquantiative x-ray diffraction (XRD) analysis.

Table A3: Analytical parameters for full geochemical analysis.

Parameter	Symbol/ Analyte	Units	Limit of Reporting
Antimony	Sb	mg/kg	0.1
Arsenic	As	mg/kg	0.1
Barium	Ba	mg/kg	0.1
Beryllium	Be	mg/kg	0.1
Bismuth	Bi	mg/kg	0.1
Cadmium	Cd	mg/kg	0.1
Caesium	Cs	mg/kg	0.1
Cerium	Ce	mg/kg	0.1
Chromium	Cr	mg/kg	0.1
Cobalt	Co	mg/kg	0.1
Copper	Cu	mg/kg	0.1
Gallium	Ga	mg/kg	0.1
Germanium	Ge	mg/kg	0.1
Hafnium	Hf	mg/kg	1
Indium	In	mg/kg	0.1
Lanthanum	La	mg/kg	0.1
Lead	Pb	mg/kg	0.1
Lithium	Li	mg/kg	0.1
Molybdenum	Mo	mg/kg	0.1
Nickel	Ni	mg/kg	0.1
Niobium	Nb	mg/kg	0.1
Rubidium	Rb	mg/kg	0.1
Selenium	Se	mg/kg	1
Silver	Ag	mg/kg	0.1
Strontium	Sr	mg/kg	0.1
Tellurium	Te	mg/kg	0.5

Parameter	Symbol/ Analyte	Units	Limit of Reporting
Thallium T	l	mg/kg	0.1
Thorium Th		mg/kg	0.1
Tin Sn		mg/kg	0.1
Tungsten W		mg/kg	0.1
Uranium U		mg/kg	0.1
Vanadium V		mg/kg	1
Yttrium Y		mg/kg	0.1
Zinc Zn		mg/kg	0.1
Zirconium Zr		mg/kg	0.5
Aluminium Al	$_2O_3$ w	t%	0.01
Calcium CaO		wt%	0.01
Chloride Cl		wt%	0.001
Iron Fe	$_2O_3$ w	t%	0.01
Magnesium MgO		wt%	0.01
Manganese MnO		wt%	0.1
Phosphorus P	$_2O_5$ w	t%	0.001
Potassium K	$_2O$ w	t%	0.001
Sodium Na	$_2O$ w	t%	0.005
Sulfur SO	$_3$ w	t%	0.001
Titanium TiO2		wt%	0.01
Loss on ignition	H_2O w	t%	0.01
Boron B		mg/kg	50
Fluoride F		mg/kg	40
Mercury Hg		mg/kg	0.1
Carbon C		wt%	0.02

Leachate characterisation

Following oxidation test work, the test samples were leached with distilled water (water:solids ratio of approx. 1:1) and the leachate analysed as indicated in Table A4 to provide a preliminary assessment of likely leachate water quality.

Table A4: Analytical parameters for leachate analysis.

Parameter	Symbol/ Analyte	Units	Limit of Reporting
pH	pH	–	0.01
EC	–	µS/cm	1
Acidity	$CaCO_3$	mg/L	1
Alkalinity	$CaCO_3$	mg/L	1
Calcium	Ca	mg/L	1
Magnesium	Mg	mg/L	1
Potassium	K	mg/L	1
Sodium	Na	mg/L	1
Sulfate	SO_4	mg/L	1
Chloride	Cl	mg/L	1
Fluoride	F	mg/L	0.1
Phosphorus	P	mg/L	0.01
Mercury	Hg	mg/L	0.0001
Aluminium	Al	mg/L	0.01
Antimony	Sb	mg/L	0.001
Arsenic	As	mg/L	0.001
Bismuth	Bi	mg/L	0.001
Boron	B	mg/L	0.05
Cadmium Cd		mg/L	0.0001
Chromium Cr		mg/L	0.001
Cobalt Co		mg/L	0.001
Copper Cu		mg/L	0.001
Iron Fe		mg/L	0.05
Lead Pb		mg/L	0.001
Manganese Mn		mg/L	0.001
Molybdenum Mo		mg/L	0.001
Nickel Ni		mg/L	0.001
Selenium Se		mg/L	0.01
Silver Ag		mg/L	0.001
Tellurium Te		mg/L	0.005
Thallium T	l	mg/L	0.001
Tin Sn		mg/L	0.001
Tungsten W		mg/L	0.001
Uranium U		mg/L	0.001
Vanadium V		mg/L	0.01
Zinc Zn		mg/L	0.005

A2.4 Geochemical Classification of Mine Materials

Static geochemical testwork results provide an indication of the ultimate potential for AMD, neutral metalliferous drainainge (NMD) and/or salinity generation. The key geochemical parameters relevant to AMD generation (NAPP, MPA, ANC, NAG_{pH}, $NAG_{4.5}$, $NAG_{7.0}$, total sulfur) were used to characterise the AMD risk for each sample. NMD risk was assessed on the basis of leachate metal content, and salinity risk on the basis of total sulfur content.

AMD and salinity risk classification was performed using Earth Systems' AMD*act* software (Acid and Metalliferous Drainage Assessment and Classification Tool), which provides a framework for the analysis of these key geochemical parameters. The geochemical classification schemes used by Earth Systems are shown in Tables A5 and A6. Full sample classifications are provided in Annex D.

Table A5: Earth Systems' geochemical classification scheme for AMD risk (AMDact)

General AMD Risk Classification	Description
Potentially Acid Forming (PAF)	High Potential for Acid Generation
	Moderate / High Potential for Acid Generation
	Moderate Potential for Acid Generation
	Low Potential for Acid Generation
Non Acid Forming (NAF)	Unlikely to be Acid Generating
	Likely to be Acid Consuming

Table A6: Earth Systems' geochemical classification scheme for salinity risk (AMDact)

Salinity Risk Classification
High Potential for Salinity Generation
Moderate Potential for Salinity Generation
Low Potential for Salinity Generation
Unlikely to be Salinity Generating

A3 Results

A3.1 Sample selection

The key lithologies identified in these geological logs are listed in Table A7.

Table A7: Key lithologies identified for the 5 Mile deposit.

Key lithologies	Lithology code	Classification	Approx. proportion of interval metres in drillholes (%)
Massive Replacement Haematite	MRH	Ore	2
Massive Replacement Magnetite	MRM	Ore	11
Replacement Haematite	FRH	Ore	19
Replacement Magnetite	FRM	Ore	31
Felsic volcanics	FVC, IVA	Waste rock	23
Sediments	SSH, SST, SSH BK	Waste rock	13
Limestone SCL		Waste rock	2

A total of 47 geological samples were selected for geochemical assessment from available drill core and laboratory pulps. A summary of the samples selection for geochemical analysis is provided in Table A8. The number of samples of each lithology was selected so as to approximate the expected proportion of each lithology to be mined based on interval metre abundance in sighted geological logs and interpretive cross-sections of the deposit.

Table A8: Summary of sample types selected for static geochemical characterisation.

Lithology	Number of samples	Percentage of total (%)	Weathering state (No.)		
			High	Transitional	Fresh
Volcanics	23	49	3	20	0
Sediments	12	26	0	3	9
Limestone	2	4	0	0	2
Ore	10	21	0	6	4
Total	47	100	3	29	15

A3.2 Ore and Product

A3.2.1 Mineralogy

The mineralogy of the wet LIMS tailings sample provided for analysis is shown in Table A9. This mineralogy is considered indicative of the non-magnetite mineralogy of the ore materials.

Table A9: Semiquantitative mineralogy for wet LIMS tailings (indicative of ore).

Mineral	wt%
Hematite	45.7
Pyrite	17.4
Chlorite	8.6
Ilmenite	6.5
Talc	6.4
Quartz	4.8
Biotite	4.2
Serpentine	3.1
Siderite	1.8
Kaolinite	1.6
TOTAL	100.0

A3.2.2 Static Geochemical Characterisation

The ore produced by the proposed mine is to be processed by dry LIMS, which will produce a product stream ('mags') to be shipped offsite, and a low-grade ore ('non-mags') that is to be stockpiled onsite.

At the time of this report, a sample of the non-mag low-grade ore material was not available for testing. The composition and characteristics of the low-grade ore are instead derived from analytical data for ore obtained in the present assessment and metallurgical data reported in Engenium (2012).

Full static geochemical results for sampled ore materials from the 5 Mile deposit are provided in Annex D. A statistical summary of key static geochemical parameters is provided in Table A10. Summary statistics for sulfur and maximum potential acidity derived from data for 377 historically sampled ore intervals from 17 drillholes materials reported in Bell (1959) are provided in Table A11.

Table A10: Key static geochemical statistics for sampled ore materials.

Parameter	Units	Statistic		
		Minimum	Mean	Maximum
Total sulfur	wt%	0.04	0.89	3.02
Sulfide sulfur (S_{TOS})	wt%	0.04	0.87	3.02
Maximum potential acidity (MPA)	kg H_2SO_4/t	1.22	27.33	92.41
Acid neutralising capacity (ANC)	kg H_2SO_4/t	6.20	18.35	40.70
Net acid producing potential (NAPP)	kg H_2SO_4/t	-25.66	8.36	83.71
pH of oxidation (NAG_{pH})	–	2.4	–	7.9

Table A11: Key static geochemical statistics for historically sampled ore materials.

Parameter	Units	Statistic		
		Minimum	Mean	Maximum
Total sulfur	wt%	0.01	2.03	9.61
Maximum potential acidity (MPA)	kg H_2SO_4/t	0.1	62.2	294

As the historical data are for a much larger number of samples (377) compared with the present sample set (10), the average sulfur and MPA statistics for the historical sample set are used hereafter for estimation of geochemical properties.

The compositions of ore, dry LIMS product and low-grade ore material based on previously reported dry LIMS metallurgical testwork (Engenium, 2013) are provided in Table A12.

Table A12: Summary of key physical and chemical characteristics of ore and dry LIMS separation streams.

Sample ID	Starting ore (head)		Mags			Non-mags		
	Fe	S	Mass	Fe	S	Mass	Fe	S
	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
NNDD012	56.5	2.80	91.8	58.1	2.19	8.2	31.0	12.04
NNDD013	52.8	0.97	86.0	57.0	0.65	14.0	26.7	2.55
NNDD014	59.3	2.83	83.8	60.9	1.73	16.2	48.6	8.96

The metallurgical results indicate that ~60 wt% of starting sulfur is diverted to the dry LIMS product. Table A13 shows the estimated average static geochemical parameters of the LIMS product and low-grade ore based on the average sulfur grade, a conservative rate of mass separation of 80% to product, a sulfur rejection rate of 40%, equal proportional separation of carbonate minerals (ANC), and the ore compositions obtained in the present investigation.

Table A13: Estimated static geochemical parameters for LIMS produce and low-grade ore material.

Parameter	Units	LIMS product	Low-grade ore
Total sulfur	wt%	1.5	4.1
Maximum potential acidity (MPA)	kg H_2SO_4/t	46	125
Acid neutralising capacity (ANC)*	kg H_2SO_4/t	18	18
Net acid producing potential (NAPP)	kg H_2SO_4/t	+28	+107

*Based on data from present analyses.

Key observations from the static geochemical testwork include:

- Low-grade ore is net acid producing with estimated average NAPP of +107 kg H_2SO_4/t.
- The dry LIMS product is also net acid producing but with a lower estimated average NAPP of +28 kg H_2SO_4/t.

- The ore material contains very little non-sulfide sulfur, indicating that total sulfur can be used to assess maximum potential sulfide-related acidity and that there is a low risk of generating other forms of acidity from sulfate salts such as jarosite.

A3.2.3 Kinetic Geochemical Characterisation

No dry LIMS product or low-grade ore samples were available for kinetic geochemical assessment at the time of this report. Kinetic geochemical information is available for a –2 mm wet LIMS tail produced during alternative metallurgical testwork; this information is used qualitatively as a preliminary and conservative assessment of likely sulfide oxidation rates for the LIMS produce and low-grade ore materials, under the following assumptions:

- The wet LIMS tail is finer-grained than the –10 mm material processed in the proposed dry LIMS process; as sulfide oxidation rates generally increase (sometimes significantly) with grain size, the sulfide oxidation rates obtained for the wet LIMS tails are expected to be higher than for the dry LIMS material streams.
- The sulfide oxidation rate, expressed as a fraction of pyrite (equivalent) oxidised per year, is a characteristic of the type and occurrence of pyrite minerals (and grain size), and can be applied to any rock of comparable lithology (in conjunction with the grain size assumption above).

The full results of static and kinetic geochemical testwork for a wet LIMS tailing sample are provided in Annex F. A summary of the key static and kinetic geochemical results is provided in Table A14, along with key parameters for simulated dry LIMS product and low-grade ore compositions.

Table A14: Key static and kinetic geochemical parameters for 5 Mile ore materials.

Parameter	Units	Tested	Simulated*		
		Wet LIMS tails	Dry LIMS product	Low-grade ore	ROM ore
Total sulfur	wt%	7.3	1.5	4.1	2.0
Sulfide sulfur (S_{TOS})	wt%	7.3	1.5	4.1	2.0
Maximum potential acidity (MPA)	kg H_2SO_4/t	223	46	125	62
Acid neutralising capacity (ANC)	kg H_2SO_4/t	11.5	18	18	18
Net acid producing potential (NAPP)	kg H_2SO_4/t	+211	+27	+107	+44
Gravimetric moisture content (GMC)	wt% H_2O	5.0	5	5	5
Pyrite oxidation rate (POR)	wt%/yr FeS_2	2.3	2.3	2.3	2.3
	$\times 10^{-9}$ kg/t/s O_2	99	27.3	20.2	55.2
	kg/t/yr S	1.7	0.46	0.34	0.93
Initial NAG rate (NAGR)	kg H_2SO_4/t/yr	<0.1	<0.1	<0.1	<0.1
Estimated lag time to onset of acid conditions (min.)	years	0.5	3	1	2
Peak NAGR	kg H_2SO_4/t/yr	4.2	0.4	1.8	0.65
Indicative longevity of sulfide oxidation	years	200	200	200	200

*Simulated using the POR of the wet LIMS tails and calculated average sulfur and ANC values for each ore category.

The predicted evolution of drainage quality for the ROM ore, dry LIMS product and low-grade ore over the first 20 years following ore extraction (ie during operations and immediately post-closure) based on the static and kinetic geochemical results above is shown in Figures A1 to A3. These figures show the intrinsic acid generation rate (AGR) for rocks with average sulfide content before the effect of ANC, as well as the net acid generation rate (NAGR) for the same rock compositions, which takes into account the expected neutralisation of acidity from the average ANC.

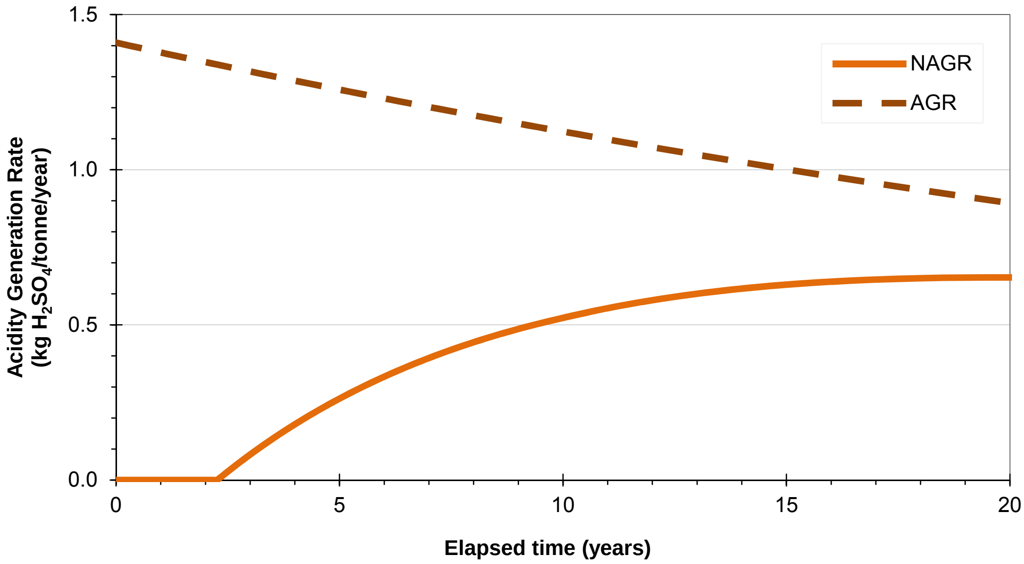


Figure A1: Predicted net acid generation over time from the ROM ore.

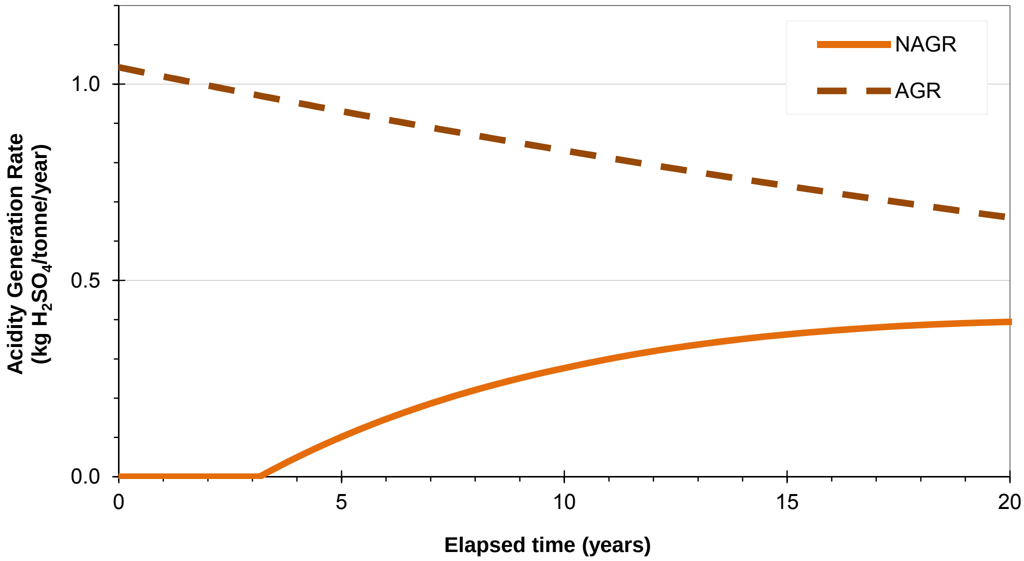


Figure A2: Predicted net acid generation over time from the dry LIMS product.

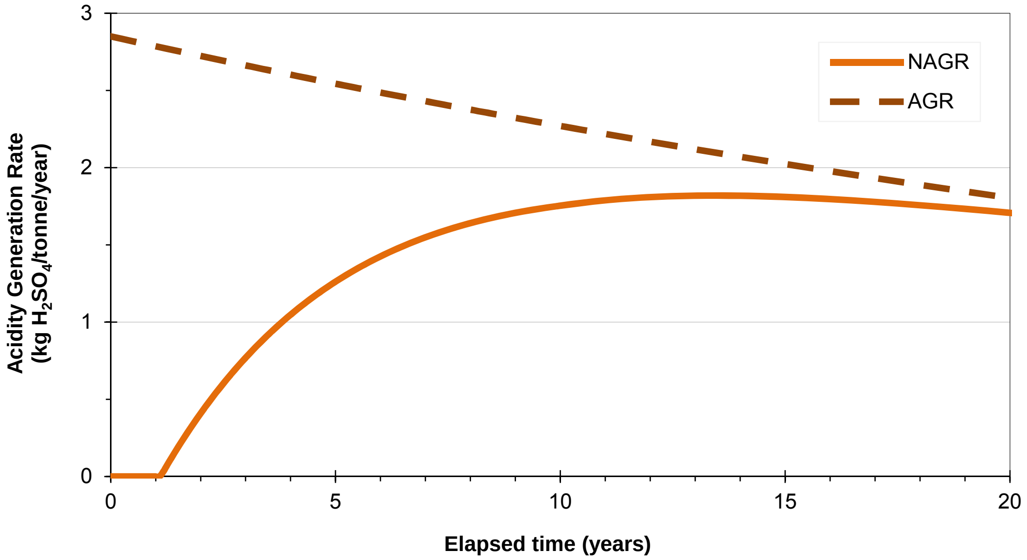


Figure A3: Predicted net acid generation over time for low-grade ore.

The acid generation characteristics of low-grade over the longer term (ie post closure) are shown in Figure A4.

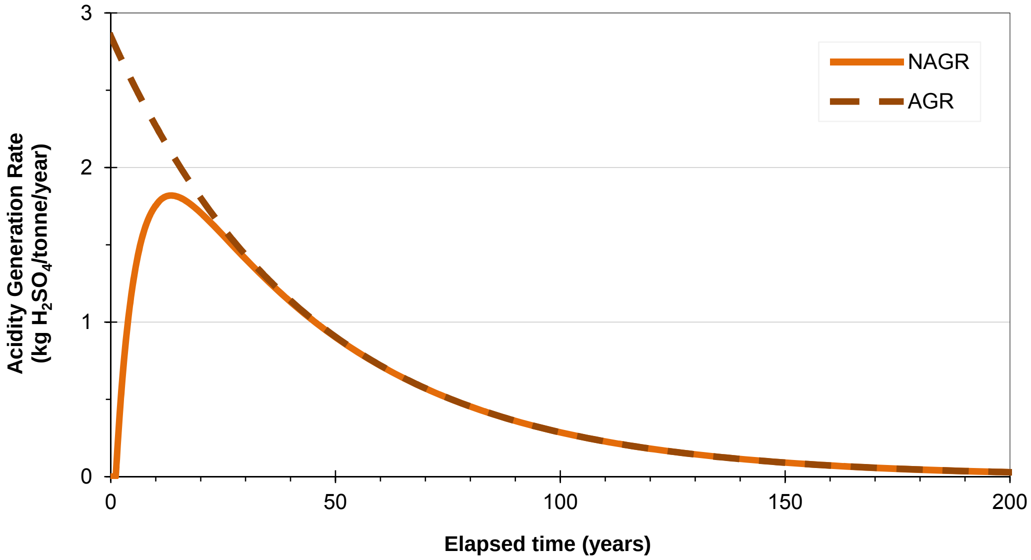


Figure A4: Predicted long-term net acid generation for low-grade ore.

Key observations from the kinetic geochemical testwork include:

- All categories of ore (ROM ore, dry LIMS product, low-grade ore) are expected to be net acid producing with a pyrite oxidation rate of approximately 2 wt% FeS_2/yr or less.
- Drainage from all ore categories is expected to be of near-neutral pH in the short term, but is expected to become acidic after 1–3 years if stored under unsaturated conditions.

- ROM ore is unlikely to become net acidic during the period that it is stored on the ROM pad (eg. <1 month); if ROM stockpiles are permitted to stand for more than ~2 years, management of acid drainage should be considered.
- Dry LIMS product is unlikely to become net acidic during the period that it is stockpiled onsite (eg. <1 month), transported or stockpiled at port (eg. <6 months); if the product is stockpiled for more than ~3 years, management of acid drainage should be considered.
- Low-grade ore has the potential to become net acidic during the period that it is likely to be stockpiled onsite (up to 10 years); management of acid drainage should be considered for any stockpile likely to stand for more than ~1 year.
- Initial drainage from all ore categories, although likely to be of near-neutral pH, has the potential to be saline and to contain elevated levels of sulfate, copper, cobalt, cadmium, manganese, nickel and zinc (see Annex F).
- The estimated peak net acidity generation rate for the low-grade ore is ~2 kg H_2SO_4/t/yr, which is expected to occur 10–15 years after extraction if stored under unsaturated conditions.

A3.2.4 Geochemical classification of ore materials

The geochemical classification of the analysed 5 Mile ore materials based on the static and kinetic geochemical testwork results commissioned in the present study is provided in Table A15. Full results of static geochemical characterisation and AMD and salinity risk assessment are provided in Annex D.

Table A15: Geochemical classification of ore materials for the 5 Mile deposit.

Ore category	Geochemical classification		
	AMD potential	NMD potential	Salinity potential
ROM ore	Potentially acid forming (PAF) Average NAPP: +44 kg H_2SO_4/t	High potential for NMD generation Components of concern: Copper, cobalt, zinc, sulfate	High potential for salinity generation
Dry LIMS product	Potentially acid forming (PAF) Average NAPP: +27 kg H_2SO_4/t	Moderate potential for NMD generation Components of concern: Copper, cobalt, zinc, sulfate	Moderate potential for salinity generation
Low-grade ore	Potentially acid forming (PAF) Average NAPP: +107 kg H_2SO_4/t	High potential for NMD generation Components of concern: Copper, cobalt, zinc, sulfate	High potential for salinity generation

A3.3 Waste Rock

A3.3.1 Mineralogy

The mineralogy of the felsic volcanics and black shale waste rock samples provided for analysis is shown in Tables A16 and A17.

Table A16: Semiquantitative mineralogy for felsic volcanic wall rock (NGS017-005).

Mineral	wt%
Albite	71.0
Chlorite	14.6
Biotite	5.5
Quartz	3.3
Muscovite	2.2
Hematite	2.1
Ankerite	0.4
Serpentine	0.4
Pyrite	0.4
TOTAL	99.9

Table A17: Semiquantitative mineralogy for black shale wall rock (NGS015-008K).

Mineral	wt%
Quartz	67.0
Muscovite	19.9
Chlorite	5.9
Biotite	2.4
Pyrite	1.9
Talc	1.5
Hematite	0.8
Albite	0.4
Ankerite	0.1
TOTAL	99.9

A3.3.2 Static Geochemical Characterisation

A statistical summary of static geochemical parameters for the analysed waste rock materials from the 5 Mile deposit is provided in Table A18. These statistics are presented according to lithology in Table A19. Full analytical results are provided in Annex D.

Table A18: Key static geochemical statistics for analysed waste rock from the 5 Mile deposit.

Parameter	Units	All waste rock		
		Min.	Mean	Max.
Total sulfur	wt%	<0.01	0.35	2.6
Maximum potential acidity (MPA)	kg H_2SO_4/t	<0.3	10.8	78
Acid neutralising capacity (ANC)	kg H_2SO_4/t	2.10	53.6	913
Net acid producing potential (NAPP)	kg H_2SO_4/t	-910	-42.9	71.5
pH of oxidation (NAG_{pH})	–	2.4	–	11.4

Table A19: Key static geochemical statistics for analysed waste rock by lithology.

Parameter	Units	Volcanics			Sediments			Limestone		
		Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
Total sulfur	wt%	<0.01	0.07	0.47	0.03	0.82	2.55	0.10	0.80	1.50
MPA	kg H_2SO_4/t	<0.03	2.17	14.4	0.92	25.0	78.0	3.06	24.5	45.9
ANC	kg H_2SO_4/t	2.10	15.0	30.70	5.60	54.7	243	69.0	491	913
NAPP	kg H_2SO_4/t	-25.4	-12.9	-1.67	-229	-29.9	71.5	-910	-467	-23.1
NAG_{pH}	–	2.4	–	11.4	2.4	–	10.8	6.0	–	11.4

The relationship between sulfur and NAG_{pH} for the analysed 5 Mile waste rock materials is shown in Figure A5.

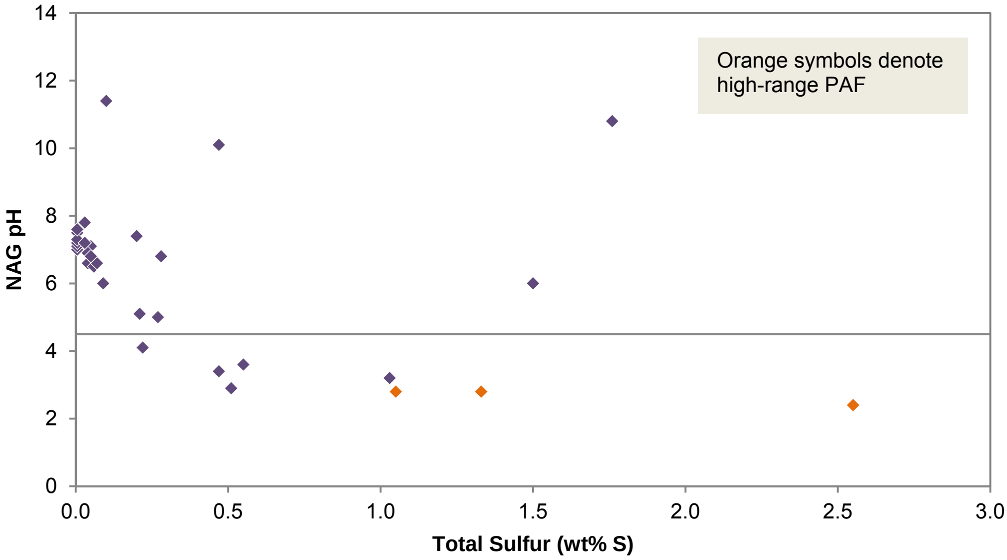


Figure A5: Total sulfur vs NAG_{pH} for waste rock materials from the 5 Mile deposit.

The relationship between ANC and NAG_{pH} for the analysed 5 Mile waste rock materials is shown in Figure A6.

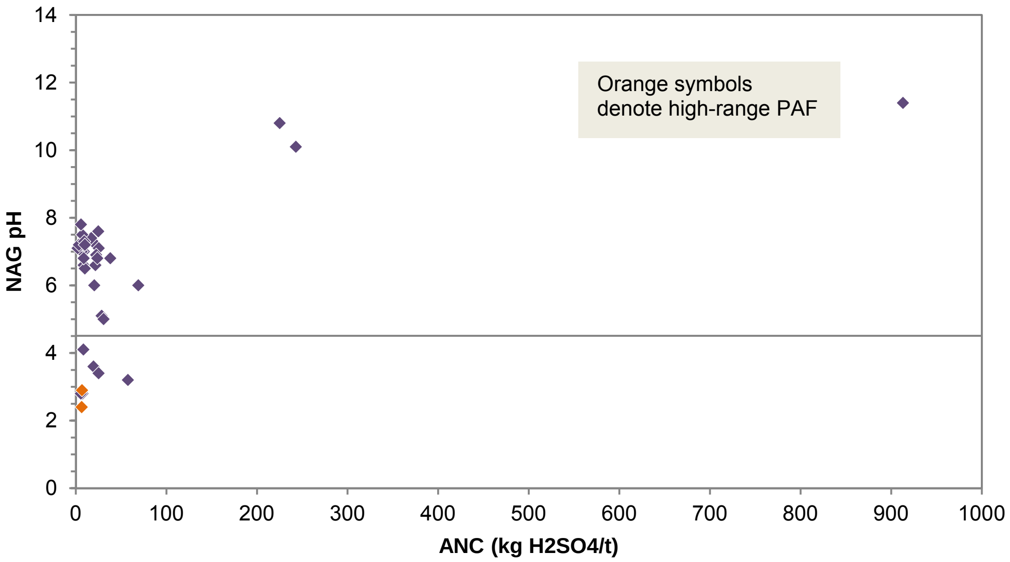


Figure A6: Acid neutralising capacity (ANC) vs NAG_{pH} for waste rock materials from the 5 Mile deposit.

The relationship between ANC and total sulfur for the analysed 5 Mile waste rock materials is shown in Figure A7.

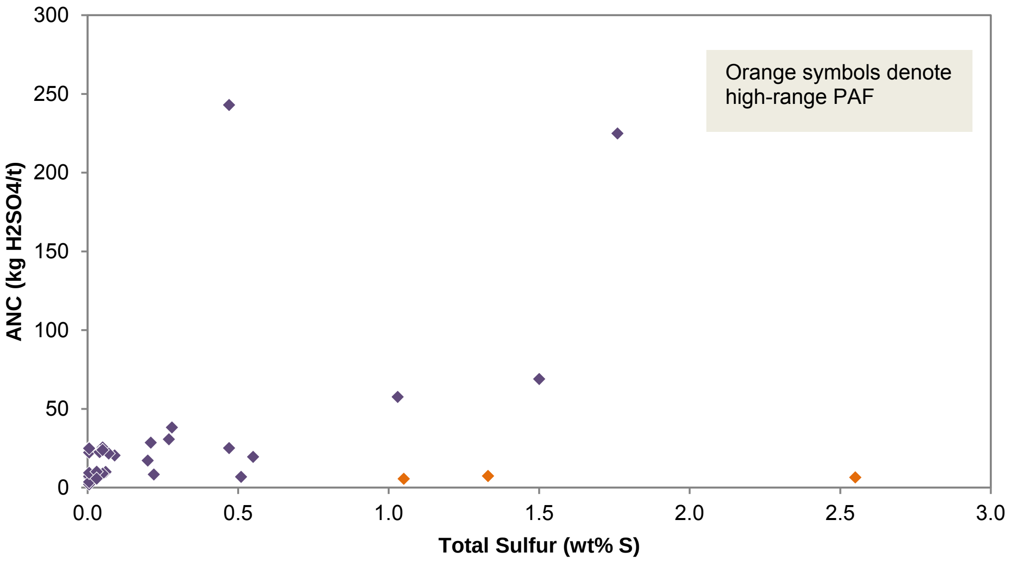


Figure A7: Acid neutralising capacity (ANC) vs total sulfur for waste rock materials from the 5 Mile deposit.

A plot of NAPP vs sulfur for the analysed 5 Mile waste rock materials is shown in Figure A8.

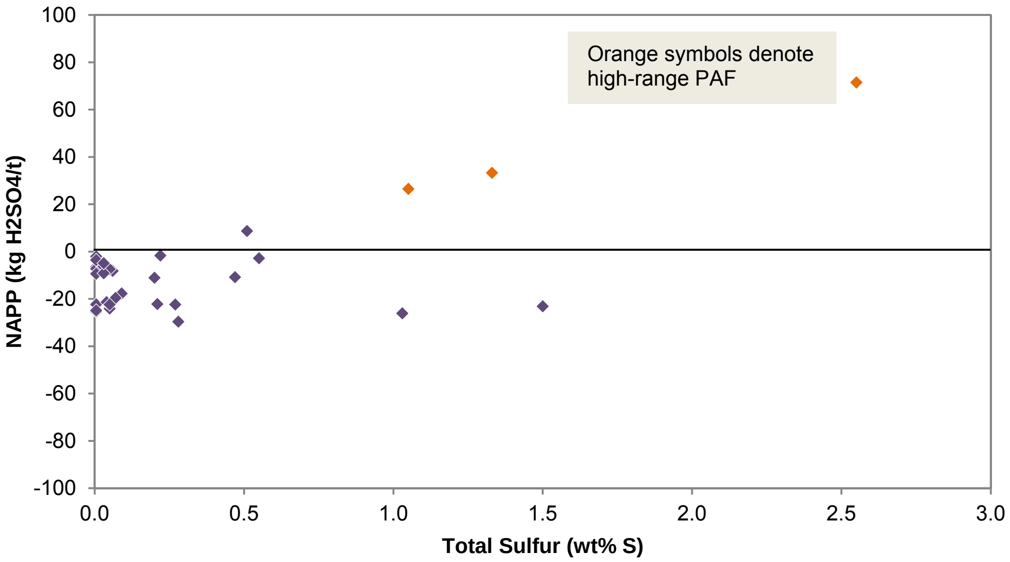


Figure A8: Net acid producing potential (NAPP) vs total sulfur for waste rock materials from the 5 Mile deposit.

A plot of NAPP vs NAG_{pH} for the analysed 5 Mile waste rock materials is shown in Figure A9.

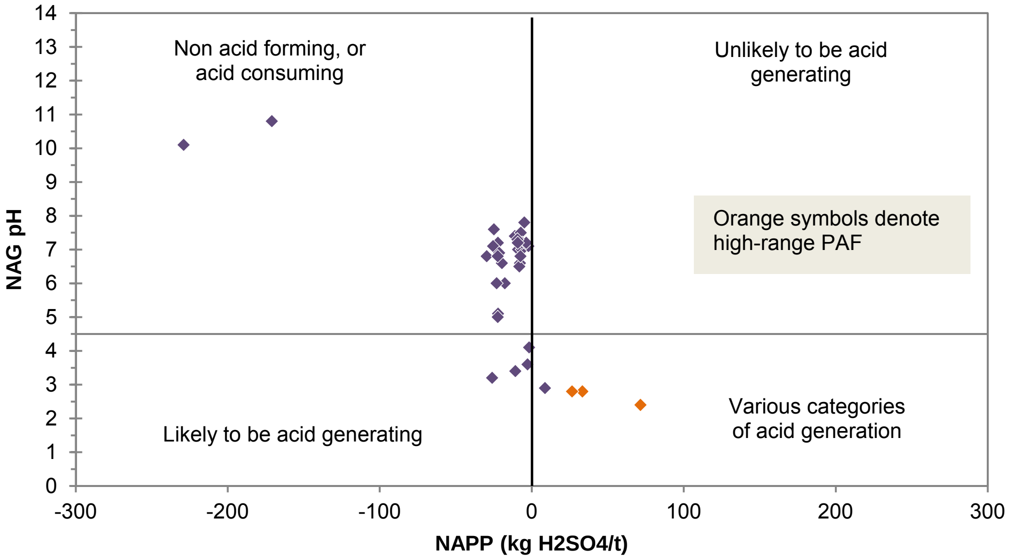


Figure A9: Net acid producing potential (NAPP) vs NAG_{pH} for waste rock materials from the 5 Mile deposit.

Key observations from the static geochemical results:

- No systematic relationships among sulfur, ANC, NAPP and NAG_{pH} are apparent in the samples analysed.
- The most reliable indicator of potentially acid forming materials is a NAG_{pH} value of less than 4.5.
- High-range PAF waste rock can be differentiated from low-range PAF and NAF materials on the basis of NAG_{pH} <= 2.8. Approximately 8% of the sampled waste rock materials are classified as high-range PAF.

A3.3.3 Kinetic Geochemical Characterisation

The full results of static and kinetic geochemical testwork for a two samples of waste rock – a representative sample of felsic volcanics from the hanging wall and a sample of black shale from the footwall – are provided in Annex F. A summary of the key static and kinetic geochemical results is provided in Table A20.

Table A20: Key static and kinetic geochemical parameters for samples of waste rock from the 5 Mile deposit.

Parameter	**Units**	**Tested material**	
		Felsic volcanics (NGS017-005)	Black shale (NGS015-008K)
Total sulfur	wt% S	0.3	1.3
Sulfide sulfur	wt% S	0.2	1.1
Maximum potential acidity (MPA)	kg H_2SO_4/t	7.3	33.7
Acid neutralising capacity (ANC)	kg H_2SO_4/t	17.0	7.1
Net acid producing potential (NAPP)	kg H_2SO_4/t	-9.6	26.6
Gravimetric moisture content (GMC)	wt% H_2O	1.0	1.0
Pyrite oxidation rate (POR)	wt% $FeS_{2/}$/yr	6.2	1.6
	×10^{-9} kg/t/s O_2	8.9	10.4
	kg/t/yr S	0.15	0.18
Initial NAG rate (NAGR)	kg H_2SO_4/t/yr	<0.1	<0.1
Estimated lag time to onset of acid conditions	years	20	2
Peak NAGR	kg H_2SO_4/t/yr	<0.1	0.3
Indicative longevity of sulfide oxidation	years	60	250

The predicted evolution of drainage quality for felsic volcanic and sediment waste rock materials based on the calculated/simulated static and kinetic geochemical results above is shown in Figures A8 and A9.

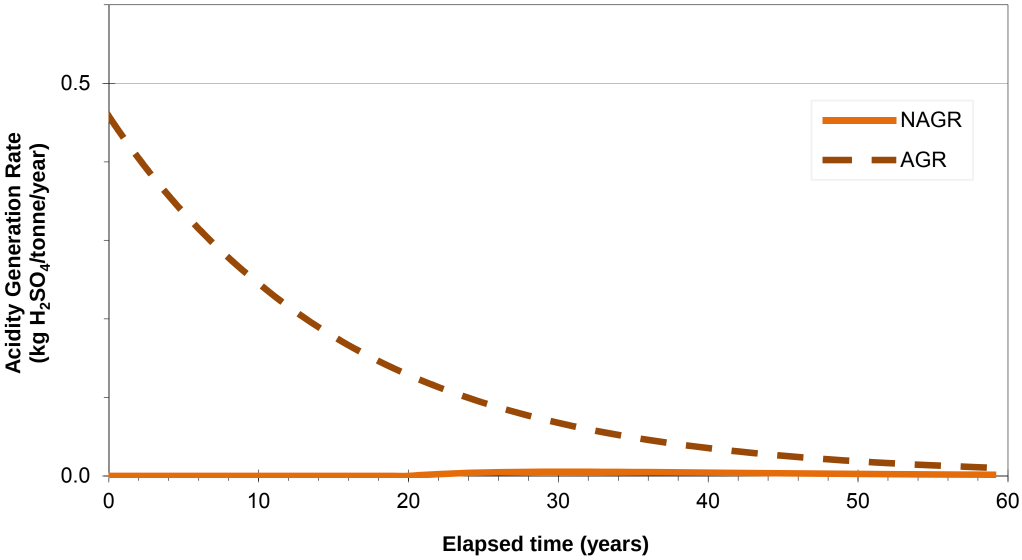


Figure A8: Predicted net acid generation over time for the felsic volcanic waste rock material (NGS017-005).

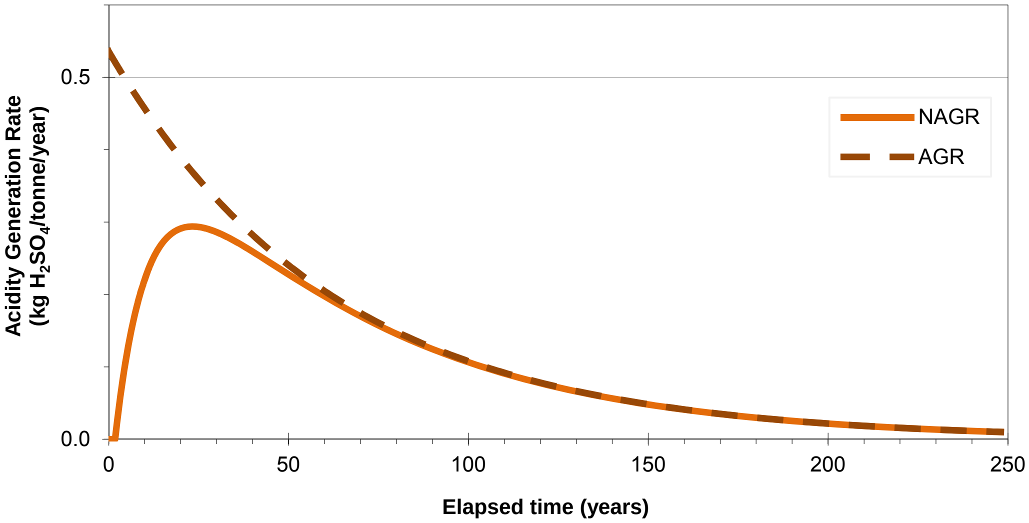


Figure A9: Predicted net acid generation over time for the black shale waste rock material (NGS015-008K).

Key observations from the kinetic geochemical testwork for the waste rock materials include:

- The felsic volcanics sample tested is not net acid producing, but has the potential to produce very marginally acid conditions over the long term (30–60 years) as acid neutralisation efficiency decreases.
- Drainage from the volcanics sample is expected to be near-neutral for the medium term, and to contain slightly elevated levels of sulfate; no metals of concern are indicated.

- The black shale is net acid producing with the potential to produce a very small amount of acid drainage after ~2 years.
- Drainage from the shale sample is initially expected to be of near-neutral pH but to contain slightly elevated levels of sulfate, cobalt and nickel.
- The estimated peak net acidity generation rate from the shale sample is ~0.3 kg H_2SO_4/t/yr, which is expected to occur ~20 years after extraction if stored under unsaturated conditions.
- Mildly saline drainage (primarily due to sulfate) is indicated for both materials.

A3.3.4 Geochemical Classification of Waste Rock Materials

A summary of the AMD, NMD and salinity risk for the analysed 5 Mile waste rock materials is provided in Table A21. Full results of acid–base accounting, sulfur speciation and AMD and salinity risk assessment are provided in Annex D.

Table A21: Geochemical classification of waste rock materials for the 5 Mile deposit.

Management category	Classification criteria	Geochemical properties		
		AMD potential	NMD potential	Salinity potential
Category A	NAPP < 0 kg H_2SO_4/t AND Sulfur < 0.3 wt%	Non acid forming (NAF)	Very low potential for NMD generation	Very low potential for salinity generation
Category B	NAPP < +10 kg H_2SO_4/t AND Sulfur > 0.3 wt%	Potentially acid forming (PAF)	Low potential for NMD generation	Low potential for salinity generation
Category C	NAPP > +10 kg H_2SO_4/t	Potentially acid forming (PAF)	Moderate potential for NMD generation	Moderate potential for salinity generation
Category N	NAPP < –40 kg H_2SO_4/t AND Sulfur < 0.6 wt%	Potentially acid consuming	Very low potential for NMD generation	Very low potential for salinity generation

The proportions of each waste rock lithology falling into each management category based on the samples analysed in the present assessment are shown in Table A22.

Table A22: Geochemical classification of waste rock materials by lithology (%).

Management category	Waste rock lithology		
	Volcanics	Sediments	Limestone
	%	%	%
Category A	91	42	50
Category B	9	25	0
Category C	0	25	0
Category N	0	8	50

A3.4 Wall Rock

The pit wall rock at the 5 Mile gold deposit is expected to consist predominantly of felsic volcanic waste rock as characterised above. Some sandstone, shale and/or limestone may be exposed in the base of the pit toward the end of operations.

The static geochemical parameters provided in Table A19 and the kinetic geochemical parameters in Table A20 can be used to assess the geochemical behaviour of general volcanic and sediment wall rock materials. The results of kinetic geochemical simulations of these materials are provided in Table A23, and the predicted evolution of drainage from the wall rock is shown in Figures A10 and A11.

Table A23: Key static and kinetic geochemical parameters for samples of waste rock from the 5 Mile deposit.

Parameter	Units	Simulated*	
		Felsic volcanics	Sediments
Total sulfur	wt% S	0.07	0.82
Sulfide sulfur	wt% S	0.07	0.82
Maximum potential acidity (MPA)	kg H_2SO_4/t	2.1	25
Acid neutralising capacity (ANC)	kg H_2SO_4/t	15	55
Net acid producing potential (NAPP)	kg H_2SO_4/t	–13	–30
Gravimetric moisture content (GMC)	wt% H_2O	1.0	1.0
Pyrite oxidation rate (POR)	wt% FeS_2/yr	6.2	6.2
	$\times 10^{-9}$ kg/t/s O_2	0.9	11.0
	kg/t/yr S	0.02	0.19
Initial NAG rate (NAGR)	kg H_2SO_4/t/yr	<0.1	<0.1
Estimated lag time to onset of acid conditions	years	N/A	30
Peak NAGR	kg H_2SO_4/t/yr	<0.1	<0.1
Indicative longevity of sulfide oxidation	years	60	250

*Simulated using the POR of the corresponding lithology (Table A17) and calculated average sulfur and ANC values (Table A16).

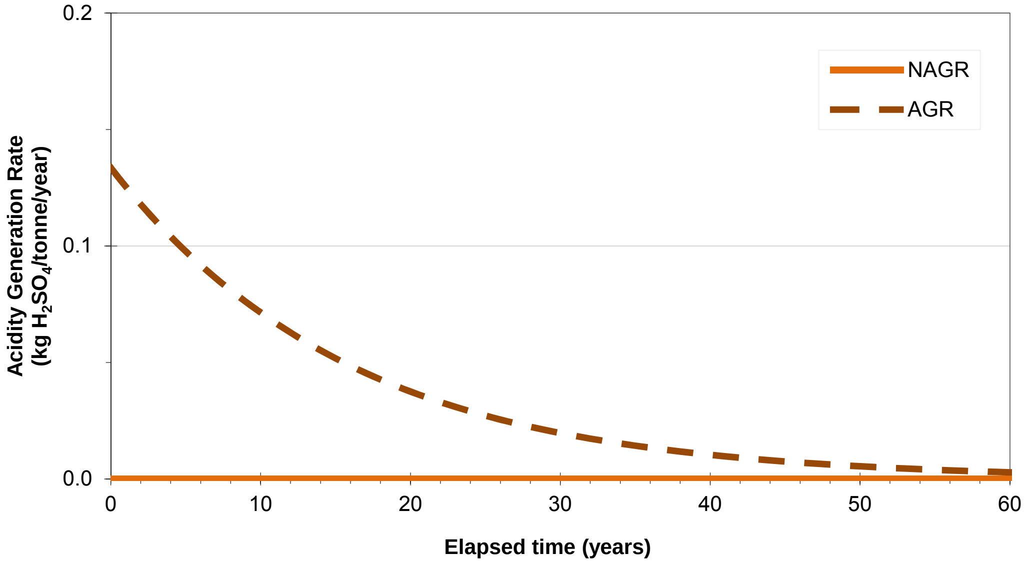


Figure A8: Predicted net acid generation over time for the felsic volcanic wall rock materials.

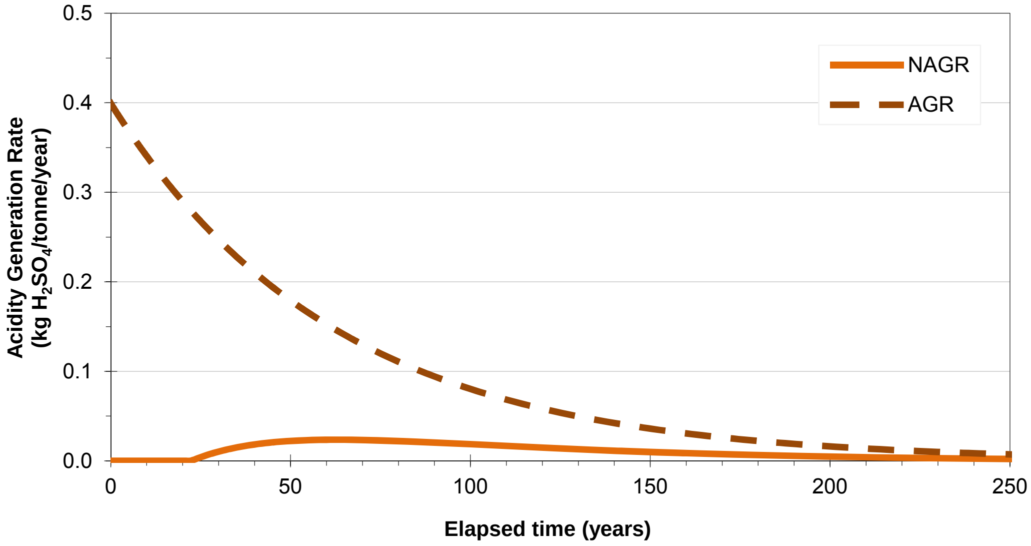


Figure A9: Predicted net acid generation over time for the sediment wall rock materials.

Wall Rock Exposure at End of Mine Life

The estimated volume of wall rock likely to be exposed to oxidising conditions at the end of operations (prior to flooding of the pit) is less than approximately 100,000 tonnes, calculated from the exposed wall rock area (approximated from the perimeter of ~1.2 km and nominal pit depth of ~200 m), a 1 m depth of oxidation, and the bulk density of the rock (2.7 t/m^3).

The felsic volcanics materials are on average non acid forming (NAF), with an average NAPP of –13 kg H_2SO_4/t (based on present data). The kinetic geochemical results suggest that acid conditions are unlikely to develop from this lithology over the long term (see Figure A8).

The sediments (sandstones and shales) are on average non acid forming (NAF), with an average NAPP of –30 kg H_2SO_4/t. The kinetic geochemical results suggest that acid conditions are unlikely to develop from this lithology over the long term (simulations suggest a very small amount of acid may be produced, but at levels significantly lower than 0.1 kg H_2SO_4/t/yr, see Figure A9).

Sulfate release rates from wall rock can be calculated from the acidity generation rates (AGRs) in Figures A8 and A9, and the mass of wall rock exposed to oxidising conditions. Assuming 70/20 /10 volcanics/sediments/limestone in wall rock (based on interpretive cross-sections and geological logs), the rate of sulfate release could potentially be on the order of ~15 tonnes of sulfate per year at the time of mine closure (70,000 t × 0.06 kg SO_4/t + 30,000 t × 0.35 kg SO_4/t).

Wall Rock Exposure Post Closure

A preliminary model of the flooded pit is shown in Figure A10. The estimated volume of highwall likely to be exposed to oxidising conditions after the pit has been flooded to the designed long-term water level (approx. 190 mAHD) is estimated to be approximately 25,000 tonnes.

The highwalls will consist of volcanics, with a sulfate generation rate of approximately 0.06 kg SO_4/t at the time of mine closure (see above). This corresponds to a flux of approximately 1.5 tonnes of sulfate per year from the exposed highwalls when the pit is first flooded (the rate of sulfate generation will decrease over time, refer to AGR plot in Figure A8). This sulfate flux will report directly to the pit lake.

The pit lake is estimated to have a maximum capacity of 6.1 GL (refer to *Attachment 5 - Surface and Groundwater Study*). The sulfate flux to the pit from the exposed highwalls therefore corresponds to the addition of 0.25 mg/L sulfate to the pit lake each year, which is very low and well within the passive treatment capacity of the pit lake.

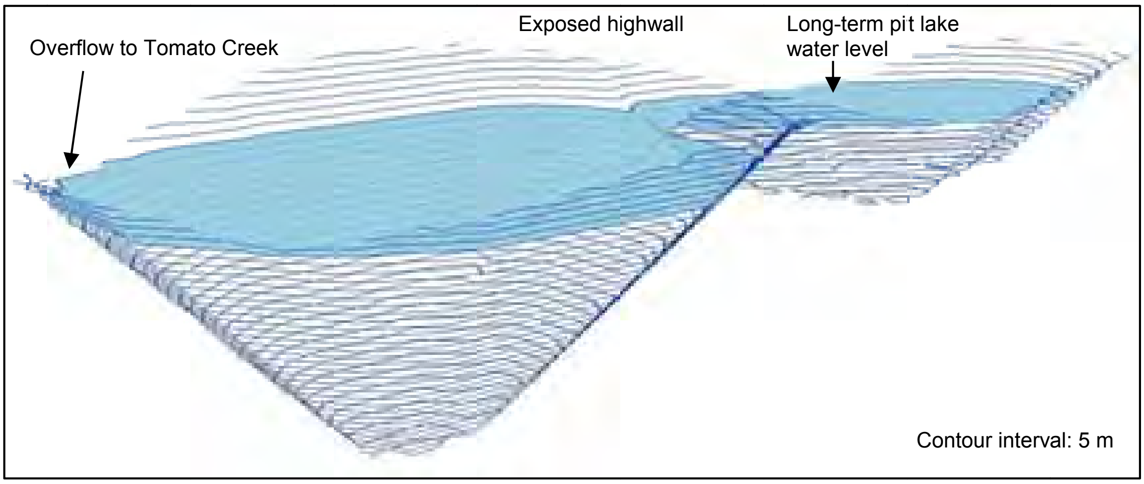


Figure A10: Preliminary pit shell showing design long-term flood level (approx. 190 mAHD).

Annex B

Acid and Metalliferous Drainage (AMD), Acidity and Acidity Load

ACID AND METALLIFEROUS DRAINAGE (AMD), ACIDITY AND ACIDITY LOAD

When sulfidic material is exposed to oxidising conditions, sulfides begin to oxidise and water subsequently transports reaction products including acidity, sulfate, iron and other metals into surface water and groundwater. This water is referred to as *acid and metalliferous drainage (AMD).*

AMD can display one or more of the following chemical characteristics:

- Low pH (typically < 4)
- High soluble metal concentrations (eg. iron, aluminium, manganese, copper, lead, zinc, cadmium, arsenic)
- Elevated total acidity (eg. 100 – 15,000 mg/L $CaCO_3$ equivalent)
- High sulfate salinity (sulfate typically 500-10,000 mg/L)
- High salinity (1000 – 20,000 µS/cm)
- Low dissolved oxygen concentrations (commonly < 6 mg/L)
- Low turbidity or total suspended solids (TSS) (combined with one or more of the above).

Acid and metal production associated with pyrite oxidation is shown in Reactions 1 to 4. An initial oxidation reaction involves the oxidation of pyrite to produce ferrous ions (Fe^{2+}), sulfate and acid, as shown in Reaction 1.

$$\underset{\text{pyrite}}{FeS_2} + \underset{\text{oxygen}}{7/2\,O_2} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{ferrous ion}}{Fe^{2+}} + \underset{\text{sulfate}}{2\,SO_4^{2-}} + \underset{\text{acid}}{2\,H^+} \qquad \text{[Reaction 1]}$$

The ferrous ions (Fe^{2+}) released by pyrite oxidation may be further oxidised to ferric ions (Fe^{3+}) consuming some acid (Reaction 2). Notice that this reaction does not involve pyrite.

$$\underset{\text{ferrous ion}}{Fe^{2+}} + \underset{\text{oxygen}}{1/4\,O_2} + \underset{\text{acid}}{H^+} \rightarrow \underset{\text{ferric ion}}{Fe^{3+}} + \underset{\text{water}}{1/2\,H_2O} \qquad \text{[Reaction 2]}$$

The ferric ions then react with water to form ferric hydroxide ($Fe(OH)_3$), which precipitates out of solution, producing additional acid (Reaction 3).

$$\underset{\substack{\text{ferric ion}\\\text{(orange precipitate)}}}{Fe^{3+}} + \underset{\text{water}}{3\,H_2O} \rightarrow \underset{\text{ferric hydroxide}}{Fe(OH)_3} + \underset{\text{acid}}{3\,H^+} \qquad \text{[Reaction 3]}$$

As shown in Reaction 3, the precipitation of ferric hydroxide is a key acid producing stage. Once sulfide minerals have oxidised and released Fe^{2+} ions, it is extremely difficult to prevent ferrous ions oxidising to ferric ions with concomitant iron hydroxide precipitation and further acid generation.

A summary reaction of the complete oxidation of pyrite (by oxygen) in mine waste materials may be expressed as follows (Reactions 1-3 combined):

$$\underset{\text{pyrite}}{FeS_2} + \underset{\text{oxygen}}{15/4\,O_2} + \underset{\text{water}}{7/2\,H_2O} \rightarrow \underset{\text{sulfate}}{2\,SO_4^{2-}} + \underset{\text{acid}}{4\,H^+} + \underset{\text{ferric hydroxide}}{Fe(OH)_3} \qquad \text{[Reaction 4]}$$

Furthermore, the presence of ferric ions (Fe^{3+}) can accelerate the oxidation of pyrite, generating additional sulfate and acid, as shown in Reaction 5.

$$\underset{\text{pyrite}}{FeS_2} + \underset{\text{ferric ion}}{14\,Fe^{3+}} + \underset{\text{water}}{8\,H_2O} \rightarrow \underset{\text{ferrous ion}}{15\,Fe^{2+}} + \underset{\text{sulfate}}{2\,SO_4^{2-}} + \underset{\text{acid}}{16\,H^+} \qquad \text{[Reaction 5]}$$

Note that in Reaction 5, 16 moles of acid are produced per mole of pyrite oxidised, as compared with 4 moles of acid generated when pyrite is oxidised by molecular oxygen (Reaction 4). Whether pyrite oxidation proceeds through Reaction 4 or 5 depends on the chemical conditions in solution at the pyrite surface. Reaction 5 suggests that soluble ferric ions can play a significant role in promoting sulfide oxidising reactions that result in AMD.

Two distinct processes, both promoted by oxidation of sulfide minerals, are responsible for decreasing the pH of an aqueous solution:

1. Acid (H^+) is directly generated by the oxidation of sulfur (Reaction 1).
2. Acid (H^+) is generated by the precipitation of metal hydroxides (eg. $Fe(OH)_3$, $Mn(OH)_4$: Reaction 3) during oxidation / neutralisation / dilution reactions.

While process 1 is controlled only by the availability of oxygen and water, process 2 depends on the solubility of the metal aqueous species, which in turn is controlled by the factors such as pH of the solution and oxidation state of the metal. In other words, the generation of acid through process 1 is limited by the sulfide oxidation rate, while the generation of acid through process 2 is delayed until metals can precipitate from solution (thus the term “latent acidity” or “mineral acidity”).

The term “acid” quantifies only the actual amount of H^+ present in solution and is generally expressed as pH. The term “acidity”, on the other hand, accounts for both the actual H^+ concentration of the aqueous solution and the potential for acid generation due to mineral or latent acidity (ie. H^+ produced by process 2).

In general acidity increases as pH decreases, but there is not always a direct relationship between acidity and pH. Based on earlier descriptions of metalliferous drainage, it is possible to have AMD with an elevated acidity but near neutral pH values. It is therefore important to quantify the contributions of both hydrogen ion concentrations (acid) and mineral contributions (latent acidity) in order to determine the total acidity of a water sample. Acidity is generally expressed as a mass of calcium carbonate ($CaCO_3$) equivalent per unit volume (eg. mg/L $CaCO_3$).

Acidity is either measured in the field or laboratory by titration or estimates of acidity can be made from water chemistry data (pH and dissolved metal concentrations) using shareware such as ABATES.

Acidity load refers to the product of the total acidity (acid plus latent acidity) and flow rate (or volume) and is expressed as a mass of $CaCO_3$ equivalent per unit time (or mass of $CaCO_3$ for a given volume of water).

$$\underset{\substack{\text{tonnes } CaCO_3 \text{ eq.}\\ \text{per year}}}{\text{Acidity load}} = \underset{\substack{\text{conversion}\\ \text{factor}}}{10^{-3}} \times \underset{\text{ML/yr}}{\text{Flow volume per year}} \times \underset{\text{mg/L}}{\text{Acidity}} \qquad \text{[Equation 1]}$$

Occasionally, the acid drainage produced via Reactions 4 and 5 is completely neutralised by dissolution reactions with naturally occurring carbonate minerals such as calcite, dolomite, ankerite and magnesite. This neutralisation process can result in the precipitation of metals such as aluminium, copper and lead which have solubilities that are pH dependent. Other metals, such as zinc, arsenic and cadmium are still relatively soluble at near neutral pH and so concentrations of these metals may remain elevated. Sulfate concentrations are not affected by these carbonate dissolution reactions and so remain elevated. This resultant near-neutral, high sulfate salinity and variably metalliferous drainage is commonly referred to as *neutral metalliferous drainage (NMD)*. While NMD still indicates the oxidation of sulfidic materials, it is less common due to the requirements for specific sulfide minerals (eg sphalerite, arsenopyrite) and a local excess of carbonate minerals.

In some environments the NMD may contain little or no soluble metals as a result of the reaction with available neutralising materials. In these environments the only indication of sulfide oxidation is high sulfate salinity or *saline drainage (SD).* The concentration of sulfate within this saline drainage is dependent on the relative proportions of calcium and magnesium in the neutralising carbonate materials. If magnesium is the dominant component of the neutralising material, high salinity is more likely to be an issue, due to the high solubility of magnesium sulfate. Conversely, if calcium is the dominant component, then the formation of gypsum precipitates will contribute to lower salinity levels.

Saline drainage generated specifically as a result of sulfide oxidation is relatively rare, in comparison with acid and/or metalliferous drainage. Nevertheless, sulfate salinity can be an important indicator of AMD issues at mine sites, and may require similar management strategies (that is, control of sulfide oxidation).

Annex C

Static Geochemical Testwork: Analytical Methods

STATIC GEOCHEMICAL TESTWORK: ANALYTICAL METHODS

This attachment provides summaries of the analytical methods used for determining static geochemical parameters (listed in Table 1). Static geochemical testwork involves a range of tests including measurements of the acidity released from a sample (acidity methods), the sulfur content of a sample (sulfur methods) as an indirect measure of acidity or acidity potential, and the acid neutralisation capacity or carbon content. A combination of these tests provides a more accurate assessment of AMD generation potential. The techniques selected for the characterisation of a particular sulfidic material will vary based on the likely material properties, Project budget and degree of accuracy required.

The following method summaries are adapted from publically available industry and government guidelines and handbooks (see references) and are provided as a guide to assist with understanding the various parameters and laboratory methods. These summaries omit important safety and quality control procedures (eg. use of blanks) as well as laboratory reagent and apparatus details, and are summarised based on standard sample weights and measures. Hence these summaries should not be used as laboratory procedures. Consult the original references if detailed laboratory methods are required.

Table C1. Summary of measured parameters for static geochemical characterisation.

Parameter	Symbol	Source	Units	Description	Brief method
Sulfur speciation					
Total sulfur	S_T	Ahern et al. 2004	wt% S	Measures pyrite and other metal or metal disulfides in a sample. Used for estimation of MPA, and with S_{HCl} gives S_{TOS}.	Oxidation in a LECO furnace.
Chromium reducible sulfur	S_{Cr}	Ahern et al. 2004	wt% S	Measures reduced inorganic sulfur compounds in a sample.	Reduced inorganic sulfur in a sample is converted to H_2S by treatment with a hot acidic $CrCl_2$ solution. Evolved H_2S is trapped in a zinc acetate solution as ZnS, which is quantified by idiometric titration.
KCl-extractable sulfur	S_{KCl}	Ahern et al. 2004	wt% S	Measures soluble plus exchangeable sulfur, sulfate from gypsum, and some sulfate from aluminium hydroxy sulfate compounds (eg. basaluminite). Used with S_{HCl} to calculate S_{NAS}.	The titrated suspension produced by TAA determination is made up with KCl, filtered and analysed for sulfate by ion chromatography. (The same method is used to determine Ca_{KCl} and Mg_{KCl}.)
HCl-extractable sulfur	S_{HCl}	Ahern et al. 2004	wt% S	Measures soluble and exchangeable sulfate, sulfate from gypsum, the relatively insoluble iron and aluminium hydroxy sulfate compounds (eg. jarosite, natrojarosite), and some sulfur from organic matter. Used with S_{KCl} to calculate S_{NAS}, and with S_T to calculate S_{TOS}.	Sample is extracted with 4 M HCl, filtered and the leachate analysed for sulfate by ion chromatography. (The same method is used to determine Ca_{HCl} and Mg_{HCl}.)
Total Oxidisable Sulfur	S_{TOS}	Ahern et al. 2004	wt% S	A measure of the oxidisable sulfur present in the sample. Can be compared with S_{Cr}	$S_{TOS} = S_T - S_{HCl}$
Net Acid-Soluble Sulfur	S_{NAS}	Ahern et al. 2004	wt% S	Measure of the jarosite and other insoluble sulfate salts in the sample. Comparable to S_{RAS}	$S_{NAS} = S_{HCl} - S_{KCl}$
Existing acidity					

Parameter	Symbol	Source	Units	Description	Brief method
KCl-extractable pH	pH_{KCl}	Ahern et al. 2004	pH unit		Sample is extracted with 1 M KCl for 4 h and stood overnight. Leachate pH is measured.
Titratable actual acidity	TAA	Ahern et al. 2004	kg H_2SO_4/t	Measures amount of free acid present in a sample.	Sample is extracted with 1 M KCl for 4 h and stood overnight. Leachate is titrated to pH 6.5.
Net acid producing potential (NAPP)					
Maximum Potential Acidity	MPA	AMIRA 2002	kg H_2SO_4/t	The stoichiometric maximum amount of acidity that a sample may generate, based on Total S or S_{Cr}.	MPA = Total S x 30.6
Acid neutralising capacity	ANC	AMIRA 2002	wt% $CaCO_3$ or kg H_2SO_4/t	Measures the inherent capacity of a sample to neutralise acid.	Stepwise addition of HCl to a sample followed by back titration with NaOH to pH 8.3.
Net Acid Producing Potential	NAPP	AMIRA 2002	kg H_2SO_4/t	Measure of the difference between the capacity of a sample to generate acid (MPA) and its capacity to neutralise acid (ANC).	NAPP = MPA - ANC
Net acid generation (NAG)					
Net acid generation: pH after oxidation	NAG_{pH}	AMIRA 2002	pH unit	The pH of a suspension following full oxidation and neutralisation reactions in the sample.	Sample is oxidised using 15% H_2O_2 and suspension pH measured.
Net acid generation: titrated to pH 4.5	$NAG_{4.5}$	AMIRA 2002	kg H_2SO_4/t	Measures acidity generated by a sample when titrated from initial pH (after oxidation and neutralisation reactions) to pH 4.5.	Sample is titrated to pH 4.5 with NaOH (concentration based on final NAG pH).
Net acid generation: titrated to pH 7.0	$NAG_{7.0}$	AMIRA 2002	kg H_2SO_4/t	Measures acidity generated by a sample when titrated from initial pH (after oxidation and neutralisation reactions) to pH 7.0.	Sample is titrated to pH 7.0 with NaOH (concentration based on final NAG pH).
Carbon					
Total carbon	C_T	Ahern et al. 2004	wt% C	Measures the total carbon content of a sample.	Sample is consumed in a combustion furnace. Carbon is measured using an IR CO_2 detection system.
Total organic carbon	C_{TO}	Ahern et al. 2004	wt% C	Measures carbon in the form of organic material in a sample.	Sample is consumed in a combustion furnace after treatment with sulfurous acid. Carbon is measured using an IR CO_2 detection system.
Inorganic carbon	C_{IN}	Ahern et al. 2004	wt% C	Measure of the inorganic carbon content of a sample	$C_{IN} = C_T$ - TOC
Carbon					
Total carbon	C_T	Ahern et al. 2004	wt% C	Measures the total carbon content of a sample.	Sample is consumed in a combustion furnace. Carbon is measured using an IR CO_2 detection system.
Total organic carbon	C_{TO}	Ahern et al. 2004	wt% C	Measures carbon in the form of organic material in a sample.	Sample is consumed in a combustion furnace after treatment with sulfurous acid. Carbon is measured using an IR CO_2 detection system.
Inorganic carbon	C_{IN}	Ahern et al. 2004	wt% C	Measure of the inorganic carbon content of a sample	$C_{IN} = C_T$ - TOC

SULFUR SPECIATION METHODS

Total Sulfur (Total S) – Ahern et. al. 2004

The measurement of total sulfur (Total S) provides a low-cost analytical technique that forms the basis of estimating the maximum potential quantity of acidity produced by the oxidation of sulfides within a sample (MPA) assuming that all sulfur present is in the form of pyrite or other metal or metalloid disulfides.

When soluble sulfate salts (eg. gypsum) and sulfur bound in organic matter are appreciable, the Total S may substantially overestimate the quantity of acidity produced. Total S does not take into account any acid neutralising capacity (ANC) present in the material.

Generally, Total S has higher detection limits than SCR and does not necessarily reflect the sulfide content.

Procedure

To determine Total S, the various constituent forms of sulfur are converted to a single form (often sulfate). This can be performed by:

Oxidation in an induction furnace (eg. Leco)

Oxidation with mineral acids (eg. HNO_3 / $HClO_4$) or NaOBr;

Dry ashing/fusion with Na_2CO_3 plus oxidising agent;

Alternatively, the non-destructive XRF method can be used.

The use of a Leco furnace enables rapid low-cost analysis of large numbers of samples, although it is generally not suitable for accurate determinations on samples with very low sulfur contents. Originally, the Leco Sulfur Analyser was designed to determine sulfur in steel using low weights < 1 g, though recent models are now available which can take up to 3 g of sample.

Chromium Reducible Sulfur (S_{Cr}) – Ahern et. al. 2004

Chromium Reducible Sulfur (S_{Cr}) is a method that measures reduced inorganic sulfur (RIS) compounds in a sample. It is not subject to significant interferences from the sulfur in either organic matter or sulfate minerals (eg. gypsum) as is the Peroxide Oxidisable Sulfur (SPOS).

The chromium reduction method is based on the conversion of RIS to H_2S by a hot acidic $CrCl_2$ solution. The evolved H_2S is trapped in a zinc acetate solution as ZnS. The ZnS may be quantified by iodometric titration. The RIS compounds measured by this method are:

Pyrite and other iron disulfides;

Elemental sulfur, and;

Acid volatile sulfides (eg. greigite and mackinawite).

The chromium reduction method can be made specific to the iron disulfide fraction if pretreatments are used to remove the acid volatile sulfides and elemental sulfur fractions.

Procedure

1. Weigh accurately the appropriate mass +/- 0.025g of finely ground (e.g. ring mill ground) oven dried (80-85° C) sample. Up to 3 g of sample is required, with the recommended amount dependent on the likely RIS content of the sample (refer to Ahern et. al., 2004 for details). Thus it is preferable to assess this using a screening analysis of Total Sulfur. If the likely RIS content is not known, then at least 0.5 of dry powdered sample should be used to ensure adequate

analytical precision. Include a solution blank to each batch and subject it to the same procedure as the sample.

2. Add 2.0 g of chromium powder and 10 mL ethanol (95 vol%) to a digestion flask and swirl to create an acidic Cr(II) solution.
3. Place the digestion flask in the heating mantle of the digestion apparatus detailed in Ahern et. al. (2004) and depicted in Figure B1.

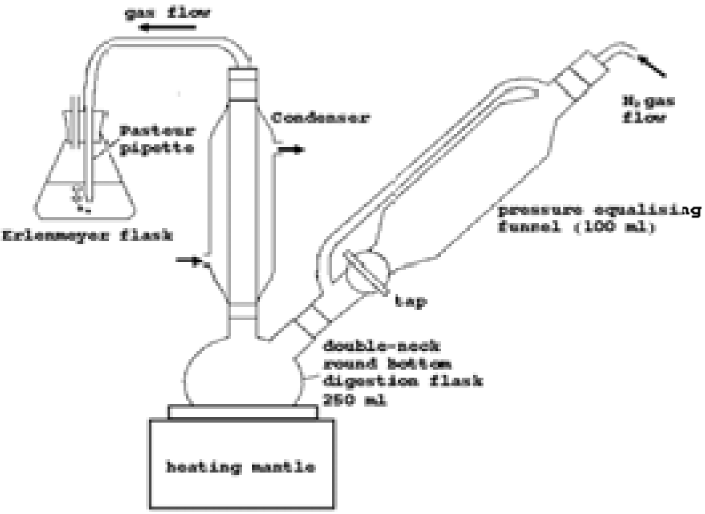


Figure B1. Schematic diagram of apparatus used during a Chromium Reducible Sulfur (S_{Cr}) determination (after Ahern et. al., 2004).

4. Add 40 mL of zinc acetate trapping solution into the flask at the outlet of the digestion apparatus.
5. Add 60 mL of 6 M HCl to the glass dispenser in the pressure equalising funnel.
6. Purge the system with N_2 gas for about 3 minutes, regulating the N_2 flow to obtain a bubble rate in the zinc acetate solution of about 3 bubbles per second. Slowly release the 6 M HCl from the dispenser.
7. Wait for 2 minutes before turning on the heating mantle. Adjust the heat so that a gentle boil is achieved. Check for efficient reflux in the condenser. Allow to digest for 20 minutes.
8. Detach the flask containing the zinc acetate solution. Add 20 mL of 6 M HCl and 1 mL of the starch indicator solution to the zinc acetate solution and swirl to mix.
9. While stirring, titrate the zinc acetate trapping solution with 0.025 M iodine solution to a permanent blue end-point.

<u>Calculations</u>

The S_{Cr} content expressed in wt.% S of oven-dry sample, can be calculated as follows (using suggested weights, volumes and concentrations):

$$\text{SCR } (\%) = ((V_1 – V_2) \text{ x } C \text{ x } 3.2066) / m$$

Where: V_1 = volume of iodine (mL) used to titrate the zinc acetate trapping solution following the sample digestion

V_2 = volume of iodine (mL) used to titrate the zinc acetate trapping solution following a blank digestion

C = Molarity of iodine solution (M)

m = sample mass (g)

KCl Extractable Sulfur (S_{KCl}) – Ahern et. al. 2004

This method determines KCl-Extractable Sulfur (S_{KCl}) following determination of pH_{KCl} and TAA on a 1:40 (solids:liquids ratio) 1 M KCl sample suspension.

This procedure recovers soluble and exchangeable sulfate that may be present in the sample as sulfuric acid readily soluble sulfate minerals (eg. gypsum, melanterite and basaluminite).

Procedure

The following procedure is performed on the titrated suspension following TAA determination:

1. Quantitatively transfer contents of titration vessels with deionised water and weigh contents.
2. Make suspensions to 400 mL and 0.2 M in KCl using deionised water.
3. Stir, then filter suspensions through high retention paper.
4. Analyse filtrate for sulfate as sulfur (mg S/L) using instrumentation that specifically determines sulfate (e.g. ion chromatography).

Calculations

The KCl-Extractable Sulfur (S_{KCl}) content expressed in wt.% S of sample, can be calculated as follows (using zero blanks, and suggested weights, volumes and concentrations):

$$S_{KCl}\ (\%) = C / 50$$

Where: C = concentration of sulfur in filtrate (mg S / L)

HCl Extractable Sulfur (S_{HCl}) – Ahern et. al. 2004

This method determines HCl-Extractable Sulfur (S_{HCl}).

This procedure recovers soluble and exchangeable sulfate present in the sample, sulfate from relatively insoluble iron and aluminium hydroxyl-sulfate compounds (eg. jarosite, natrojarosite) as well as some sulfur from organic matter.

Procedure

1. Weigh 2.00 +/- 0.10 g of pulverized (eg. ring mill) oven dried (at 80–85 ºC) sample into an extraction container.
2. Add 80 mL of 4 M HCl to make a 1:40 (solids:liquid ratio) suspension and stopper the bottle.
3. Shake overnight (16 +/- 0.5 hours) on reciprocal or end-over-end shaker.
4. Centrifuge or filter suspension to obtain a clear extract.
5. Analyse filtrate for sulfate as sulfur (mg S/L) using instrumentation that specifically determines sulfate (e.g. ion chromatography).

Total Oxidisable Sulfur (S_{TOS}) – Ahern et. al. 2004

The Total Oxidisable Sulfur (S_{TOS}) is the calculated difference between Total Sulfur (Total S) and 4 M HCl-Extractable Sulfur (S_{HCl}). The S_{TOS} parameter is a useful low cost screening approach to determine pyrite content in samples, but gives no estimate of ' actual acidity' from previous or partial oxidation of sulfides.

While this is a conservative approach, use of the S_{Cr} technique could result in lower treatment costs or in some cases even clarify that no treatment is required.

Calculation

$$S_{TOS} \text{ (wt.\% S)} = \text{Total S} - S_{HCl}$$

Net Acid Soluble Sulfur (S_{NAS}) – Ahern et. al. 2004

Considerable retained acidity may be stored samples in the form of jarosite and similar relatively insoluble iron and aluminium hydroxyl-sulfate compounds. Their acidity and sulfur is not recovered in the 1 M KCl suspensions of TAA and S_{KCl}. These compounds are soluble in 4 M HCl as are all other sulfate species. The difference in the sulfur extracted by 4 M HCl (S_{HCl}) and 1 M KCl (S_{KCl}) provides an estimate of the insoluble (jarositic) sulfur content of the sample. On highly organic ASS soils, 4 M HCl may extract appreciable organic sulfur and (unless a sulfate specific technique, such as ion chromatography is used) may inflate the SNAS result.

Calculation

$$S_{NAS} \text{ (wt.\% S)} = S_{HCl} - S_{KCl}$$

EXISTING ACIDITY METHODS

KCl Extractable pH (pH_{KCl}) and Titratable Actual Acidity (TAA) – Ahern et. al. 2004

This method determines the pH of a sample in a 1:40 M KCl suspension, and to estimate the actual acidity of the sample. The actual acidity is the soluble and readily exchangeable acidity such as any sulfuric acid in the sample and the acidity released upon the dissolution of readily soluble minerals such as melanterite.

Procedure

1. Pulverise a representative sample in a ring-mill.
2. Add 2.00 +/- 0.1 g of pulverised, oven-dried (at 80-85 °C) sample to an extraction container and make a 1:40 (solids:liquid) suspension with 80 mL of 1 M KCl solution.
3. Shaker for 4 +/- 0.25 hours, the (keeping container the sealed) allow the bottle and contents to stand overnight (12 to 16 hours).
4. Resuspend contents after standing by briefly shaking sample container (~5 min) immediately prior to titration. While stirring, measure and record the pH of the suspension (pH_{KCl}). Titrate as follows, depending on the measured pH_{KCl}:

If pH_{KCl} is < 4.0, titrate while stirring to pH 6.5 using standardised 0.25 M NaOH and record titre volume.

If pH_{KCl} is 4.0-6.5, titrate while stirring to pH 6.5 using standardised 0.05 M NaOH and record titre volume.

If pH_{KCl} is ≥ 6.5, no titration is required and the TAA is zero.

Calculations

The Titratable Actual Acidity (TAA) is expressed in mol H+ / tonne oven-dry sample. When using suggested weights, volumes and for 0.05 M NaOH, TAA can be calculated as follows:

$$\text{TAA (mol } H^+ \text{ / tonne)} = 25 \times V$$

Where: V = volume of NaOH used in titration (mL)

Notes

Retain the titrated suspension if KCl-Extractable Sulfur (S_{KCl}), KCl-Extractable Calcium (Ca_{KCl}) and KCl-Extractable Magnesium (Mg_{KCl}) are subsequently to be determined.

NET ACID PRODUCING POTENTIAL AND NET ACID GENERATION

Maximum Potential Acidity (MPA) – AMIRA, 2002

Maximum Potential Acidity (MPA) measures the theoretical maximum quantity of acidity that can be produced in a sample by the process of sulfide oxidation, by assuming that the measured sulfur content occurs as pyrite (FeS_2):

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

The total sulfur content (Total S) is commonly used because of the difficulty and costs involved in routinely determining the speciation of sulfur forms within samples and determining reactive sulfide-sulfur contents. This is a conservative approach because not all sulfur present is necessarily pyritic sulfur. Non-acid producing forms of sulfur such as sulfates (e.g. anhydrite, gypsum, barite), organic sulfur and native sulfate may exist in the sample, and some sulfur may occur as other metal sulfides (e.g. covellite, chalcocite, sphalerite, galena), which yield less acidity that pyrite when oxidised, thus the MPA calculated from the total sulfur may be higher than the actual acid-producing potential.

Calculation

The Maximum Potential Acidity (MPA) expressed in kg H_2SO_4 per tonne of sulfidic material can be calculated as follows:

$$MPA\ (kg\ H_2SO_4\ /\ tonne) = Total\ S\ (wt.\%\ S) \times 30.6$$

Acid Neutralising Capacity (ANC) – AMIRA, 2002

ANC measures the inherent capacity of a sample to neutralise acid. ANC is typically determined by the addition of hydrochloric acid to a sample, then back-titration with sodium hydroxide to determine the amount of acid consumed.

The Acid Neutralising Capacity Back Titration Method (ANCBT) is a similar procedure, however it is used in studies of ASS (Ahern et. al., 2004) rather than AMD (AMIRA, 2002), with results given as '$CaCO_3$ equivalent'.

Procedure

1. Weigh 2.00 g of air dried, pulverised (< 60 mesh) sample in a beaker. Add a suitable volume of standardised HCl to the sample (nominally up to 20 mL of 0.2 M HCl for some samples) in a step wise manner until pH values are between approximately 2.0 to 2.5. Also add approximately 20 mL deionised (or distilled) water to the sample / HCl mixture.
2. Place beaker on a moving hot plate (80 to 90°C) for approximately 2 hours to allow the sample / acid mix to react.
3. Remove from hot plate and add a second volume of HCl as required (nominally up to another 20 mL of 0.1 to 0.5 M HCl for some samples until the pH value is between 0.8 and 1.5). ANC reactions still undergoing completion will be discernable by a fizzing in the flask or beaker.
4. Note: if the original pH value in Step 1 was between 0.8 and 1.5, no additional acid is required.

5. If the second addition of HCl was required, place samples on a moving hot plate (80 to 90 °C) for approximately 22 hours to ensure that the reaction goes to completion.
6. Standardise all sample volumes to nominally 125 mL by adding deionised or distilled water. Further pH adjustment may be made by stepwise HCl addition if required (refer Steps 3 and 4).
7. Back-titrate the sample / acid mix to pH 8.3 using nominally 0.2 M NaOH (i.e. the same molarity as the HCl used).
8. Note: A pH value of 8.3 is used as it is the equivalence point for carbonate / bicarbonate in natural waters.

Calculations

The Acid Neutralising Capacity (ANC) in kg H_2SO_4 per tonne of material can be calculated as follows if suggested weights, volumes and concentrations are used:

$$\text{ANC (kg } H_2SO_4 \text{ / tonne)} = (M_{HCl} \times V_{HCl}) - (M_{NaOH} \times V_{NaOH}) \times 49 / m$$

Where: M_{HCl} = molarity of HCl used (mol / L)

V_{HCl} = volume of HCl used (mL)

C_{NaOH} = concentration of NaOH used in titration (mol / L)

V_{NaOH} = volume of NaOH used in titration (mL)

m = sample mass (g)

Notes

This analytical procedure is derived from the AMD literature (AMIRA, 2002). The ANCBT procedure used in studies of ASS is similar, however different sample weights, concentrations of standards, titration endpoints and heating times are used. Refer to Ahern et al. (2004) for details.

Net Acid Producing Potential (NAPP) – AMIRA, 2002

NAPP is a measure of the difference between the capacity of a sample to generate acid (MPA) and its capacity to neutralise acid (ANC). In some situations, NAPP tests have a tendency to overestimate the acid production potential because it does not differentiate between acid producing and non-acid producing forms of sulfur. NAPP is a worst case scenario test and is therefore useful for screening samples into potential acid producers and non-acid producers.

Calculation

The Net Acid Producing Potential (NAPP) expressed in kg H_2SO_4 per tonne of sulfidic material can be calculated as follows:

$$\text{NAPP (kg } H_2SO_4 \text{ / tonne)} = \text{MPA} - \text{ANC}$$

Notes

Samples are classified as either potentially acid consuming (negative NAPP value; MPA < ANC) or potentially acid generating (positive NAPP value; MPA > ANC).

Net Acid Generation (NAG) –AMIRA, 2002

The NAG test involves the reaction of a sample with hydrogen peroxide to rapidly oxidise any sulfide minerals that may be present. Both acid generation and neutralisation reactions occur simultaneously, with the net result representing a direct measure of the amount of acid generated. NAG tests are sometimes preferred to the more time consuming NAPP tests as a first pass indication of acid generating capacity due to their relative simplicity and lower cost. The NAG test assumes that 100% of both the sulfide-sulfur oxidation reactions and the carbonate and other neutralising mineral reactions go to completion. The NAG test gives three measurements:

Net Acid Generation – pH after oxidation (NAG_{pH}), pH units

Net Acid Generation – titrated to pH 4.5 ($NAG_{4.5}$), kg H_2SO_4/tonne

Net Acid Generation – titrated to pH 7.0 ($NAG_{7.0}$) , kg H_2SO_4/tonne

Procedure

The standard NAG test involves the following steps:

1. Core or bulk rock samples should be crushed to a nominal size of <4 mm and a representative sub-sample pulverised to approximately 200 Mesh (<75µm). Tailing and process residue samples can be tested ‘as received’.
2. Add 2.5 ± 0.1 g of pulverised sample to a 500 mL conical flask or equivalent.
3. Use a 250 ml graduated cylinder to measure 250 ml of a solution of 15% H_2O_2 and carefully add the hydrogen peroxide to the conical flask.
4. Place a watchglass on top of the beaker and place the beaker in a fume hood or well-ventilated area.
5. Allow the sample to react until 'boiling' or effervescence ceases. This may require the sample to be left overnight, at longest.
6. After the reaction, place the beaker on a hot plate and gently heat the sample until effervescence stops or for a minimum of 2 hours.

   Note: Do not allow the sample to boil dry. Add deionised water as required to maintain the volume approximately constant.
7. Allow the sample to cool to room temperature.
8. Rinse any sample that has adhered to sides of flask down into the solution using deionised water. Add deionised water to give a final volume of 250 mL.
9. Record the pH of the solution. This pH measurement is referred to as the NAGpH.
10. Titrate the solution to pH 4.5 and 7.0, while stirring, with the appropriate NaOH conc. based on NAGpH as follows:
    - when NAGpH is > 2 Titrate with 0.10 M NaOH
    - when NAGpH is = 2 Titrate with 0.50 M NaOH

    Note: Titration to both pH 4.5 and 7.0 is recommended to assist with the interpretation of results. Titration to pH 4.5 accounts for acidity due to Fe, Al and most of the hydrogen ion. Any additional acidity accounted for in titration between pH 4.5 and pH 7 is usually indicative of soluble metals such as Cu and Zn.

Calculations

The sample NAG, expressed in kg H_2SO_4 / tonne of sulfidic material can be determined according to:

$$\text{NAG (kg } H_2SO_4 \text{ / tonne)} = (49 \times V \times C) / m$$

Where: V = titre volume (NaOH) (mL)

C = molarity of NaOH used for titration (mol / L)

m = mass of sample used (g)

Notes

If NAG value exceeds 25 kg H_2SO_4 per tonne, then the procedure may need to be repeated using a lower sample weight (e.g. 1.0 g sample).

Annex D

Static Geochemistry Results

Hole ID	Sample ID	Lab ID	Interval		Lithology	Weathering code	Material Type	Static Geochemistry										AMD Status	AMD Classification	Salinity Classification*
			From	To				Total S	NAPP	NAG$_{pH}$	NAG$_{4.5}$	NAG$_{7.0}$	ANC	ANC	S$_{Cr}$	S$_{HCl}$	S$_{KCl}$			
			m	m				%	kg H$_2$SO$_4$/t	pH Unit	kg H$_2$SO$_4$/t	kg H$_2$SO$_4$/t	kg H$_2$SO$_4$/t	wt% CaCO$_3$	wt% S	wt% S	wt% S			
NDD015	NGS015-009	N15-020	32	34	MRH	fr	Ore	0.11	-2.8	6.6	<0.1	0.1	6.2	0.6	<0.005	0.02	<0.02	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD015	NGS015-010	N15-027	46	48	MRM	fr	Ore	3.02	83.7	2.4	60.8	64.2	8.7	0.9	2.090	<0.02	<0.02	PAF	High Potential for Acid Generation	High Potential for Salinity Generation
NDD016	NGS016-009	N16-024	38	40	FRH	sw	Ore	0.29	2.5	4.8	<0.1	1.1	6.4	0.6	<0.005	0.04	<0.02	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD016	NGS016-010	N16-047	78	80	FRM	fr	Ore	0.90	-3.7	3.6	1.7	5.1	31.2	3.2	0.630	<0.02	<0.02	PAF	Low Potential for Acid Generation	Low Potential for Salinity Generation
NDD017	NGS017-007		18	20	FRH	mw	Ore	0.07	-25.6	6.9	<0.1	<0.1	27.8	2.8	0.059	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD017	NGS017-008	N17-042	66	68	FRM	fr	Ore	1.13	6.7	3.6	1.9	11.1	27.9	2.8	<0.005	<0.02	<0.02	PAF	Low Potential for Acid Generation	Moderate Potential for Salinity Generation
NDD019	NGS019-009	N19-020	34	36	FRM	sw	Ore	2.17	25.7	2.7	16.8	22.2	40.7	4.2	0.943	0.14	0.14	PAF	Moderate Potential for Acid Generation	Moderate Potential for Salinity Generation
NDD019	NGS019-010	N19-030	50	52	FRH	mw	Ore	0.08	-4.2	7.5	<0.1	<0.1	6.6	0.7	<0.005	<0.02	<0.02	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD020	NGS020-008	N20-016	28	30	FRM	mw	Ore	1.12	20.3	3.0	9.4	14.5	14.0	1.4	0.853	<0.02	<0.02	PAF	Low Potential for Acid Generation	Moderate Potential for Salinity Generation
NDD020	NGS020-009	N20-022	38	40	FRH	mw	Ore	0.04	-12.8	7.9	<0.1	<0.1	14.0	1.4	<0.005	<0.02	<0.02	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD015	NGS015-001K		2	6	FVC	hw	WR	<0.01	-7.2	7.0	<0.1	<0.1	7.2	0.7	<0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD015	NGS015-002		12	14	FVC	hw	WR	0.04	-7.7	6.6	<0.1	13.7	8.9	0.9	0.030	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD015	NGS015-003		18	20	FVC	mw	WR	0.05	-24.1	7.1	<0.1	<0.1	25.6	2.6	0.023	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD015	NGS015-004		20	22	FVC	mw	WR	<0.01	-22.3	7.2	<0.1	<0.1	22.3	2.3	0.010	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD015	NGS015-005	N15-054	90	92	SSH	fr	WR	0.28	-29.6	6.8	<0.1	0.1	38.2	3.9	0.223	<0.02	<0.02	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD015	NGS015-006	N15-064/065	106	108	SSH	fr	WR	0.55	-2.8	3.6	1.9	4.9	19.6	2.0	0.392	<0.02	<0.02	PAF	Low Potential for Acid Generation	Low Potential for Salinity Generation
NDD015	NGS015-007		116	118	SST	fr	WR	0.51	8.7	2.9	10.6	13.7	6.9	0.7	0.445	0	0	PAF	Low Potential for Acid Generation	Low Potential for Salinity Generation
NDD015	NGS015-008K		124	128	SSH (BK)	fr	WR	1.33	33.3	2.8	28.4	36.3	7.4	0.8	1.100	0	0	PAF	Moderate / High Potential for Acid Generation	Moderate Potential for Salinity Generation
NDD016	NGS016-001		2	4	FVC	ls	WR	<0.01	-9	7.0	<0.1	<0.1	9	0.9	<0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD016	NGS016-002		8	10	FVC	ls	WR	0.09	-17.7	6.0	<0.1	0.2	20.5	2.1	0.091	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD016	NGS016-003		12	14	FVC	ls	WR	<0.01	-25.4	7.1	<0.1	<0.1	25.4	2.6	<0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD016	NGS016-004		20	22	FVC	tj	WR	0.06	-8.2	6.5	<0.1	0.2	10	1	0.060	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD016	NGS016-005		26	28	FVC	tj	WR	0.47	-10.8	3.4	2.8	6.5	25.2	2.6	0.378	0	0	PAF	Low Potential for Acid Generation	Low Potential for Salinity Generation
NDD016	NGS016-006	N16-071	122	124	SSH	fr	WR	2.55	71.5	2.4	48.7	56.7	6.5	0.7	1.890	<0.02	<0.02	PAF	Moderate / High Potential for Acid Generation	Moderate Potential for Salinity Generation
NDD016	NGS016-007		126	128	SSH	fr	WR	1.05	26.5	2.8	24.8	32.2	5.6	0.6	0.928	0	0	PAF	Moderate / High Potential for Acid Generation	Moderate Potential for Salinity Generation
NDD016	NGS016-008		140	142	SST	fr	WR	0.2	-11.1	7.4	<0.1	<0.1	17.2	1.8	0.177	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD017	NGS017-001		2	4	FVC	sw	WR	<0.01	-6.5	7.0	<0.1	<0.1	6.5	0.7	<0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD017	NGS017-002		8	10	FVC	sw	WR	0.22	-1.7	4.1	0.5	2.4	8.4	0.8	0.194	0	0	PAF	Low Potential for Acid Generation	Low Potential for Salinity Generation
NDD017	NGS017-003		12	14	FVC	sw	WR	0.04	-21.4	6.9	<0.1	<0.1	22.6	2.3	0.023	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD017	NGS017-004		26	28	FVC	sw	WR	0.21	-22.2	5.1	<0.1	1.1	28.6	2.9	0.175	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD017	NGS017-005		34	36	FVC	tj	WR	0.27	-22.4	5.0	<0.1	1	30.7	3.1	0.240	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD017	NGS017-006		38	40	IVA	tj	WR	0.07	-19.6	6.6	<0.1	<0.1	21.7	2.2	0.057	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD019	NGS019-001		2	4	FVC	hw	WR	<0.01	-7.2	7.5	<0.1	<0.1	7.2	0.7	0.006	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD019	NGS019-002K		4	8	FVC	mw	WR	0.03	-6.3	7.2	<0.1	<0.1	7.2	0.7	<0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD019	NGS019-003		10	12	FVC	mw	WR	0.05	-7.4	6.8	<0.1	<0.1	8.9	0.9	0.037	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD019	NGS019-004		16	18	SSH	sw	WR	0.05	-22.4	6.8	<0.1	<0.1	23.9	2.4	0.036	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD019	NGS019-005	N19-044	72	74	SCL	fr	WR	1.50	-23.1	6.0	<0.1	0.9	69.0	7.0	1.170	<0.02	<0.02	NAF	Unlikely to be Acid Generating	Moderate Potential for Salinity Generation
NDD019	NGS019-006	N19-043	74	76	SSH	fr	WR	1.76	-171.0	10.8	<0.1	<0.1	225.0	22.9	1.390	0.02	0.03	NAF	Unlikely to be Acid Generating	Moderate Potential for Salinity Generation
NDD019	NGS019-007	N19-051	86	88	SSH	mw	WR	0.47	-229.0	10.1	<0.1	<0.1	243.0	24.8	0.339	<0.02	<0.02	NAF	Likely to be Acid Consuming	Low Potential for Salinity Generation
NDD019	NGS019-008	N19-054	92	94	SSH	fr	WR	1.03	-26.1	3.2	5.7	10.9	57.6	5.9	0.814	<0.02	<0.02	PAF	Low Potential for Acid Generation	Moderate Potential for Salinity Generation
NDD020	NGS020-001		0	2	FVC	ew	WR	<0.01	-2.1	7.1	<0.1	<0.1	2.1	0.2	<0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD020	NGS020-002		2	4	FVC	mw	WR	<0.01	-3.6	7.2	<0.1	<0.1	3.6	0.4	0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD020	NGS020-003K		8	12	FVC	tj	WR	<0.01	-9.4	7.3	<0.1	<0.1	9.4	1	<0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD020	NGS020-004		10	12	FVC	sw	WR	0.03	-9.2	7.2	<0.1	<0.1	10.1	1	0.020	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD020	NGS020-005		16	18	FVC	sw	WR	<0.01	-24.9	7.6	<0.1	<0.1	24.9	2.5	<0.005	0	0	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD020	NGS020-006	N20-039/040	64	66	SSH	mw	WR	0.03	-4.9	7.8	<0.1	<0.1	5.8	0.6	<0.005	<0.02	<0.02	NAF	Unlikely to be Acid Generating	Low Potential for Salinity Generation
NDD020	NGS020-007	N20-042	68	70	SCL	fr	WR	0.10	-910.0	11.4	<0.1	<0.1	913.0	93.1	0.083	<0.02	<0.02	NAF	Likely to be Acid Consuming	Low Potential for Salinity Generation

Annex E

Kinetic Geochemical Testwork: Analytical Methods

KINETIC GEOCHEMICAL TESTWORK: ANALYTICAL METHODS

Kinetic geochemical testwork is used to determine the rate of decay of sulfide minerals over time (ie. the pyrite equivalent oxidation rate, or POR). This type of testwork is usually conducted to complement prior static geochemical tests on sulfidic materials. With knowledge of the POR, the rate of pollution generation from sample material can be estimated. Other information that can be obtained from kinetic testwork includes indicative leachate water chemistry, the reactivity of different sulfide minerals, availability of neutralising minerals and the lag time to consume neutralising minerals (ie. onset of acidic discharges). Some kinetic techniques permit assessment of the pyrite oxidation rate as a function of different variables such as moisture content or particle size distribution, that are important controls on the rate of oxidation.

Common laboratory scale kinetic geochemical testwork techniques include:

- Free draining column leach testwork;
- Humidity cell testwork; and
- Oxygen consumption testwork.

Kinetic geochemical testwork involves a number of measurements over time to measure or infer the POR. Oxygen consumption techniques measure the POR directly via measurements of oxygen concentration over time; where as column leach and humidity cell testwork infers POR based on the rate of sulfate release measured over time in the leachate from a sample (ie. the sulfate release rate).

This attachment provides a summary of industry-standard analytical techniques for column leach tests and humidity cell tests. These methods are adapted from publically available industry and government guidelines and handbooks (see references). There is currently no industry standard for oxygen consumption testwork, a number of techniques have been developed in recent years to provide direct measurement of POR.

These method summaries are provided only as a guide to assist with understanding the various laboratory procedures, and omit important safety and quality control information as well as laboratory reagent and apparatus details. Hence these summaries are not intended to be used as laboratory procedures.

COLUMN LEACH TESTWORK

The free draining leach column test is the most commonly used type of column leach test. The method described here is a standard method for such a test, as specified in AMIRA (2002). In this test, leach columns are loaded with sample and subjected to wetting and drying cycles to encourage oxidation and flushing of oxidation products. Water flushed through the column sample is collected and analysed for a variety of parameters. The test period varies depending on material characteristics and the investigation needs, and the results are usually reviewed on a 6-monthly basis, usually taking 6 to 24 months to complete. Sub-samples of leached solids may also be taken before testing and at intervals during testing for geochemical and mineralogical analysis in order to track changes in mineral constituents over time.

Operation of the leach column is designed to achieve a weekly wet–dry cycle and a monthly flushing cycle. A schematic illustration of the test set-up for free draining column leach tests is shown in Figure 1.

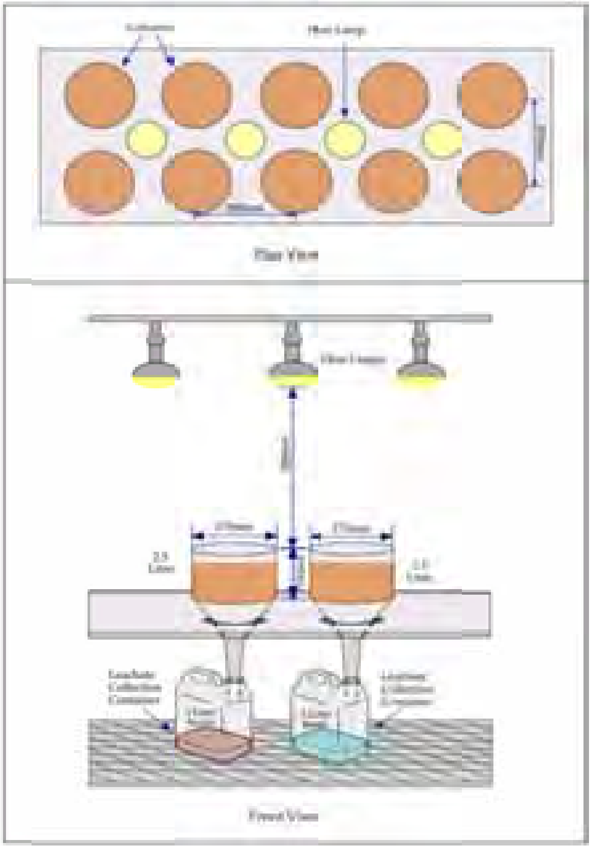


Figure 1. Schematic diagram of a typical free draining leach column set-up using conventional Buchner Funnels (AMIRA, 2002).

Samples are usually crushed (not pulverised) to ~4 mm, and typically 2 kg of the crushed material is loaded into the column and the weight recorded. Heat lamps are operated on a cyclic basis, 8–10 h per day 5 days per week, to heat the surface of the sample to 30–35 °C. Deionised water is applied to the surface of the sample once a week to moisten the sample. Additional deionised water is added every 4th week to flush the sample, and after 2 days the leachate is collected and tested for pH, EC, alkalinity/acidity and sulfate concentrations. The leachate can also be subjected to elemental analysis. Leachate chemistry and volume are used to quantify the rate of sulfate release over 6 to 24 months as a basis for estimating POR. Estimates of POR in this way are based on the assumption that all sulfate in the leachate is associated with sulfide oxidation.

Column leach tests are generally better suited to coarse-grained materials (eg. sand size and greater) than fine-grained materials such as tailings or materials with high clay content. This is due to the poor free draining properties of fine grained materials.

HUMIDITY CELL TESTWORK

The two most common standards for humidity cell tests are the AMIRA (2002) standard and the ASTM D5744-07e1 (2007).

The method outlined below is the AMIRA (2002) humidity cell test specifically designed for mine waste rock. The method uses an environmentally controlled cell containing the sample to maintain constant temperature (25 ºC) and humidity (65 %RH), in order to optimise sulfide oxidation processes. An example of a typical humidity cell test set-up is shown in Figure 2. The test duration is dependent on the objectives of the test, analytes measured, and composition of the sample. Typically a humidity cell test is conducted over 4 to 5 months.

Figure 2: A typical humidity cell test set-up (INAP, 2010)

Tests are conducted using a representative 1 kg sample of air-dried, as-received rock, screened at 1.7 mm with crushing as necessary. Each week, the sample in the humidity cell is flooded with deionised water and left to stand for 1 hour. The leachate is then drained from the sample and collected through a basal outlet. The ASTM method for humidity cell testwork only differs in that it involves a periodic dry air cycle.

As with column leach testwork, leachate chemistry and volume are used to quantify the rate of sulfate release over 6 to 24 months as a basis for estimating POR. Estimates of POR in this way are based on the assumption that all sulfate in the leachate is associated with sulfide oxidation.

OXYGEN CONSUMPTION TESTWORK

Oxygen consumption tests involve the direct measurement of the rate of oxygen consumption, which in the case of sulfidic material corresponds to the rate of pyrite (equivalent) oxidation. There is no standard method for oxygen consumption testing of sulfidic materials, various methods have been developed in recent years by the Australian Nuclear Science and Technology Organisation (ANSTO) and several universities in North America. Earth Systems' OxCon method is described below.

A typical OxCon apparatus is shown in Figure 3. The test works by isolating a known mass of sulfide-bearing material and a known volume of oxygen inside a sealed vessel. Once testwork is instigated, oxygen consumption proceeds via pyrite oxidation, and is measured using an electrochemical sensor. Carbon dioxide generated as a result of bacterial oxidation of organic carbon (for acid sulfate soils or coal samples) or from neutralisation reactions involving carbonate minerals is measured using a carbon dioxide adsorbent located inside the sample chamber during oxygen consumption testing. The mass change in adsorbent can be used to estimate the extent of neutralisation that occurred during testing.

OxCon tests are typically conducted over 2 to 8 weeks, and can be used for any grain size.

Figure 3. OxCon test set-up.

Once testwork is completed, the sample can be flushed with deionised water and analysed to identify indicative water quality. The leachate parameters measured are similar to those measured for column leach or humidity cell testwork.

REFERENCES

ASTM (2007). Standard Test Method for Laboratory Weathering of Solid Materials Using a Humidity Cell (Designation: D5744 - $07^{\varepsilon 1}$). ASTM International.

AMIRA (2002) *ARD Test Handbook.* AMIRA Project P387A Prediction and Control of Acid Mine Drainage. AMIRA International.

INAP. 2010. Global Acid Rock Drainage Guide – Chapter 5b Laboratory Kinetic Test. http://www.gardguide.com/index.php/Chapter_5b#5.4.12_Laboratory_Kinetic_Tests

Annex F

Kinetic Geochemistry Results (OxCon Reports)

OxCon
Oxygen consumption test

EARTH SYSTEMS
ANALYTICAL

LABORATORY REPORT

DATE OF ISSUE	13 September 2013
LABORATORY REPORT REFERENCE	NOWAN1202

PROJECT	Nowa Nowa Iron Project
CLIENT	Eastern Iron Limited
– CONTACT	Greg DeRoss

NUMBER OF SAMPLES	3
NUMBER OF TESTS	3
NUMBER OF SIMULATIONS	5

In this Laboratory Report:

- Summary of laboratory results
- Individual test reports
- Test method and terminology

SUMMARY OF LABORATORY RESULTS

Earth Systems Analytical was engaged to determine the static and kinetic geochemical characteristics of representative mine materials from the proposed 5 Mile iron deposit in Nowa Nowa, Victoria. OxCon testing was conducted on three geological samples that were dried to a gravimetric moisture content of 1–5%. The test results were then used to simulate average compositions of two lithologies of waste rock and three categories of ore.

A summary of the data acquired through this testwork and the simulation results is provided on this page. Detailed results can be found in the individual test and simulation reports (on the following pages).

Samples and preparation

The following three bulk samples were received for analysis:

- Wet LIMS tails from metallurgical testing
- A sample of felsic volcanic waste rock (NGS017-005)
- A sample of black shale (NGS015-008K)

Samples were prepared as follows.

- Homogenisation
- Drying at 40 °C to complete dryness;
- Rewetting to the target moisture content.

Subsamples were submitted for static geochemical characterisation, analysis of major and trace element chemistry, X-ray diffraction analysis for mineralogy and determination of acid buffering characteristic curves.

Summary of results

A summary of the key static and kinetic geochemical parameters for all of the tested samples and simulations is provided in Tables 1 and 2.

Table 1: Key static and kinetic geochemical parameters of tested samples.

Parameter	Units	Tested samples		
		Wet LIMS Tails	Volcanics NGS017-005	Black shale NGS015-008K
Total sulfur	wt% S	7.3	0.27	1.3
Sulfide sulfur	wt% S	7.3	0.24	1.1
Maximum potential acidity (MPA)	kg H_2SO_4/t	223.1	7.3	33.7
Acid neutralising capacity (ANC)	kg H_2SO_4/t	11.5	17.0	7.1
Net acid producing potential (NAPP)	kg H_2SO_4/t	211.6	-9.6	26.6
Gravimetric moisture content (GMC)	wt% H_2O	5.0	1.0	1.0
Pyrite oxidation rate (POR)	wt%/yr FeS_2	2.3	6.2	1.6
	$\times 10^{-9}$ kg/t/s O_2	98.7	8.9	10.4
	kg/t/yr S	1.66	0.15	0.18
Initial NAG rate (NAGR)	kg H_2SO_4/t/yr	<0.1	<0.1	<0.1
Estimated lag time to onset of acid conditions	years	0.4	20	1.9
Peak NAGR	kg H_2SO_4/t/yr	4.2	<0.1	0.3
Indicative longevity of sulfide oxidation	years	200	60	250
AMD potential		High	Unlikely	Moderate /high
NMD potential		High	Low	Moderate
Salinity potential		High	Low	Moderate

*POR (wt% FeS_2/yr): Weight percentage of available pyrite oxidised per year (ie. normalised with respect to pyrite content).

Table 2: Key static and kinetic geochemical parameters of simulated compositions.

Parameter	Units	Simulated compositions				
		ROM Ore	Dry LIMS Product	Low-Grade Ore	Volcanics (WR)	Sediments (WR)
Total sulfur	wt% S	2.0	1.5	4.1	0.07	0.82
Sulfide sulfur	wt% S	2.0	1.5	4.1	0.07	0.82
Maximum potential acidity (MPA)	kg H_2SO_4/t	62.1	45.9	125.5	2.1	25.1
Acid neutralising capacity (ANC)	kg H_2SO_4/t	18.3	18.3	18.3	15.0	54.7
Net acid producing potential (NAPP)	kg H_2SO_4/t	43.8	27.6	107.1	-12.9	-29.6
Gravimetric moisture content (GMC)	wt% H_2O	5.0	5.0	5.0	1.0	1.0
Pyrite oxidation rate (POR)	wt%/yr FeS_2	2.3	2.3	2.3	6.2	1.6
	$\times 10^{-9}$ kg/t/s O_2	27.3	20.2	55.2	0.9	11.0
	kg/t/yr S	0.46	0.34	0.93	0.02	0.19
Initial NAG rate (NAGR)	kg H_2SO_4/t/yr	<0.1	<0.1	<0.1	<0.1	<0.1
Estimated lag time to onset of acid conditions	years	2.3	3.2	1.2	N/A	23
Peak NAGR	kg H_2SO_4/t/yr	0.7	0.4	1.8	<0.1	<0.1
Indicative longevity of sulfide oxidation	years	200	200	200	60	250
AMD potential		Moderate /high	Moderate	High	Unlikely	Low
NMD potential		High	Moderate	High	Unlikely	Moderate
Salinity potential		High	Moderate	High	Unlikely	Moderate

*POR (wt% FeS_2/yr): Weight percentage of available pyrite oxidised per year (ie. normalised with respect to pyrite content).

TEST REPORT

SAMPLE DETAILS

Date	13 September 2013	Prepared for	Eastern Iron Limited
Sample ID	LIMS Tails	Project	Nowa Nowa Iron Ore Project
Sample Description	Wet LIMS tails sample from metallurgical testing	Particle size	Sand
		Reference lithology	Tailings

SUMMARY OF SAMPLE ENVIRONMENTAL BEHAVIOUR

AMD/NMD/salinity risk	High potential for acid generation
Longevity of sulfide oxidation	Sulfide oxidation (primary acidity generation and water quality impacts) expected to persist for ~200 years
Predicted water quality impacts	NMD expected initially, onset of acid conditions expected after ~5 months, peak acid generation at ~7 years
Leachate components of concern	Copper; cobalt, zinc; cadmium, manganese, nickel, sulfate
Key reactive minerals	Pyrite, serpentine

STATIC GEOCHEMISTRY

SULFUR SPECIATION

Total sulfur	7.3 wt% S
Readily soluble acid-forming sulfate sulfur	<0.02 wt% S
Readily soluble non-acid-forming sulfate sulfur	0.03 wt% S
Sparingly soluble acid-forming sulfate sulfur	<0.01 wt% S
Sulfide sulfur	7.3 wt% S
Equivalent pyrite content	13.6 wt% FeS_2

ACID–BASE ACCOUNTING

Acid neutralising capacity	ANC	11.5 kg H_2SO_4/t
Maximum potential acidity	MPA	223 kg H_2SO_4/t
ANC/MPA ratio		<0.1
Net acid producing potential	NAPP	+211 kg H_2SO_4/t

NET ACID GENERATION

pH after oxidation	NAG_{pH}	2.3 (pH)
Net acid generation to pH 4.5	$NAG_{4.5}$	82 kg H_2SO_4/t
Net acid generation to pH 7.0	$NAG_{7.0}$	91 kg H_2SO_4/t
Net acid generation, pH 4.5 to pH 7.0		8 kg H_2SO_4/t

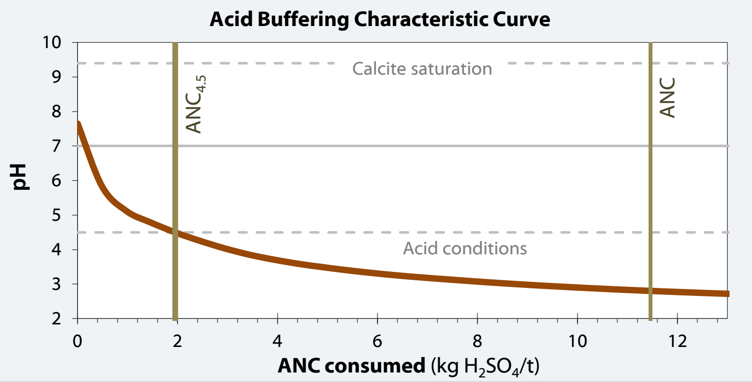
RISK CLASSIFICATION*

AMD Risk	**High potential for acid generation**
NMD Risk	High potential for NMD generation
Salinity Risk	High potential for salinity generation

*Determined from static geochemistry

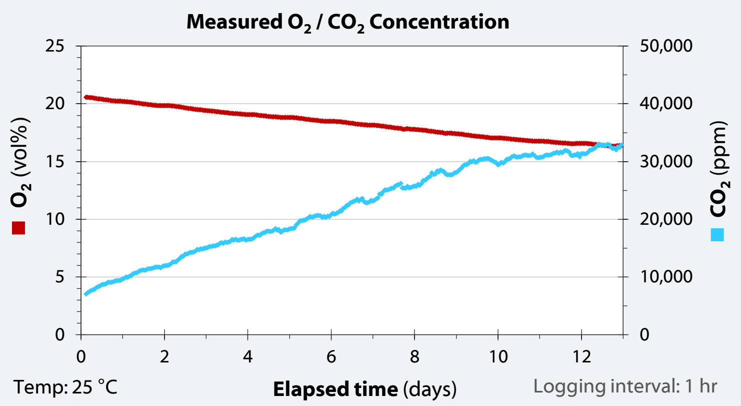
ACID NEUTRALISATION EFFICIENCY

Acid neutralisation capacity to pH 4.5	$ANC_{4.5}$	2.0 kg H_2SO_4/t
Acid conditions (MPA > $ANC_{4.5}$)		Highly likely


Acid Buffering Characteristic Curve

KINETIC GEOCHEMISTRY

OXYGEN CONSUMPTION TESTWORK


Measured O_2 / CO_2 Concentration

Temp: 25 °C

Logging interval: 1 hr

Sample mass (dry)	4.42 kg	GMC*	5.0 wt% H_2O

*Gravimetric moisture content

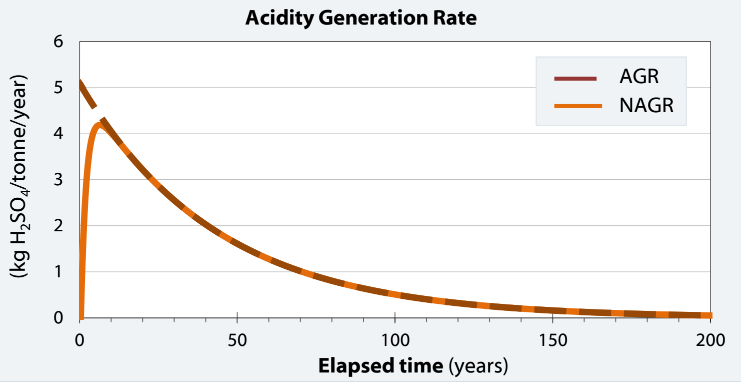
PYRITE OXIDATION RATE

Oxygen consumption rate	OCR	0.27 mmol/kg/day
Pyrite oxidation rate*	POR	2.3 wt% Pyr/yr
POR (intrinsic units)		99 ×10^{-9} kg O_2/t/s 1.7 kg S/t/yr
Acidity generation rate (intrinsic)	AGR	5.1 kg H_2SO_4/t/yr

*Normalised to sample pyrite content (ie., fraction of pyrite oxidised per year)

NET ACID GENERATION RATE

Initial net acid generation rate	NAGR	<0.1 kg H_2SO_4/t/yr
Estimated lag time to onset of acid conditions		5 months
Estimated peak NAGR (at ~7 years)		4.2 kg H_2SO_4/t/yr
Estimated half-life of reactive sulfide		30 years
Estimated longevity of sulfide oxidation		200 years


Acidity Generation Rate

OxCon
Oxygen consumption test

EARTH SYSTEMS
ANALYTICAL

TEST REPORT

MAJOR AND TRACE ELEMENT CHEMISTRY

Element	Symbol	SAMPLE SOLIDS	NAG LEACHATE mg/kg solids	OXCON LEACHATE mg/L
Calcium	Ca	0.19 wt%	–	432
Magnesium	Mg	6.51 wt%	–	492
Potassium	K	0.56 wt%	–	47.0
Sodium	Na	0.08 wt%	–	177
Chloride	Cl	210 mg/kg	–	171
Fluoride	F	0.4 mg/kg	–	0.4
Carbon	C	0.16 wt%	–	–
Sulfur/sulfate	S/SO_4	7.32 wt%	–	3,430
Aluminium	Al	3.02 wt%	–	0.06
Iron	Fe	45.8 wt%	–	<0.05
Manganese	Mn	0.03 mg/kg	–	20.1
Phosphorus	P	0.05 mg/kg	–	<0.01
Antimony	Sb	<0.001 mg/kg	–	<0.001
Arsenic	As	0.001 mg/kg	–	0.001
Barium	Ba	– mg/kg	–	–
Beryllium	Be	– mg/kg	–	–
Bismuth	Bi	<0.001 mg/kg	–	<0.001
Boron	B	0.15 mg/kg	–	0.15
Cadmium	Cd	0.0037 mg/kg	–	0.0037
Caesium	Cs	– mg/kg	–	–
Cerium	Ce	– mg/kg	–	–
Chromium	Cr	<0.001 mg/kg	–	<0.001
Cobalt	Co	2.51 mg/kg	–	2.51
Copper	Cu	38.3 mg/kg	–	38.3
Gallium	Ga	– mg/kg	–	–
Germanium	Ge	– mg/kg	–	–
Hafnium	Hf	– mg/kg	–	–
Indium	In	– mg/kg	–	–
Lanthanum	La	– mg/kg	–	–
Lead	Pb	<0.001 mg/kg	–	<0.001
Lithium	Li	– mg/kg	–	–
Mercury	Hg	<0.0001 mg/kg	–	<0.0001
Molybdenum	Mo	<0.001 mg/kg	–	<0.001
Nickel	Ni	0.222 mg/kg	–	0.222
Niobium	Nb	– mg/kg	–	–
Rubidium	Rb	– mg/kg	–	–
Selenium	Se	<0.01 mg/kg	–	<0.01
Silver	Ag	<0.001 mg/kg	–	<0.001
Strontium	Sr	– mg/kg	–	–
Tellurium	Te	<0.005 mg/kg	–	<0.005
Thallium	Tl	<0.001 mg/kg	–	<0.001
Thorium	Th	– mg/kg	–	–
Tin	Sn	<0.001 mg/kg	–	<0.001
Titanium	Ti	1,300 mg/kg	–	–
Tungsten	W	– mg/kg	–	–
Uranium	U	0.001 mg/kg	–	0.001
Vanadium	V	<0.01 mg/kg	–	<0.01
Yttrium	Y	– mg/kg	–	–
Zinc	Zn	1.56 mg/kg	–	1.56
Zirconium	Zr	– mg/kg	–	–

OXCON LEACHATE – GENERAL PARAMETERS

pH	5.6
Electrical conductivity (EC)	3.1 mS/cm
Alkalinity	<1 mg/L $CaCO_3$
Acidity – measured	103 mg/L $CaCO_3$
Acidity – calculated[1]	104 mg/L $CaCO_3$
POR based on sulfate release[2]	5.0 wt% Pyr/yr

[1] Calculated from metal content.

[2] Strongly influenced by sample storage history.

MINERALOGY

Mineral	wt%
Hematite	45.7
Pyrite	17.4
Chlorite	8.6
Ilmenite	6.5
Talc	6.4
Quartz	4.8
Biotite	4.2
Serpentine	3.1
Siderite	1.8
Kaolinite	1.6
	0.0
	0.0
	0.0
	0.0
TOTAL	100.0

Mineralogy determined by X-ray diffraction (XRD) analysis.

SAMPLE AS TESTED

CHEMISTRY NOTES

Chemical abundance index (CAI)	Low	Medium	High
Sample solids	CAI based on the geochemical abundance index of enrichment relative to average global crustal abundance.		
NAG leachate	CAI based on the leachable chemical content and the solids CAI.		
OxCon leachate	CAI based on the chemical enrichment in reference to ANZECC (2000) guideline levels for 99% aquatic ecosystem protection.		

All chemical analyses were conducted by NATA-accredited laboratories.

Ver. 7.10

OxCon
Oxygen consumption test

EARTH SYSTEMS
ANALYTICAL

TEST REPORT

SAMPLE DETAILS

Date	13 September 2013	Prepared for	Eastern Iron Limited
Sample ID	NGS017-005	Project	Nowa Nowa Iron Ore Project
Sample Description	Felsic volcanics (hanging wall) waste rock	Particle size	−20 mm
		Reference lithology	Felsic volcanics

SUMMARY OF SAMPLE ENVIRONMENTAL BEHAVIOUR

AMD/NMD/salinity risk	Unlikely to be acid generating
Longevity of sulfide oxidation	Sulfide oxidation (primary acidity generation and water quality impacts) expected to persist for ~60 years
Predicted water quality impacts	NMD expected, acid conditions not expected in the long term
Leachate components of concern	None
Key reactive minerals	Ankerite, pyrite

STATIC GEOCHEMISTRY

SULFUR SPECIATION

Total sulfur	0.27	wt% S
Readily soluble acid-forming sulfate sulfur	<0.02	wt% S
Readily soluble non-acid-forming sulfate sulfur	–	wt% S
Sparingly soluble acid-forming sulfate sulfur	–	wt% S
Sulfide sulfur	0.24	wt% S
Equivalent pyrite content	0.45	wt% FeS_2

ACID–BASE ACCOUNTING

Acid neutralising capacity	ANC	17.0	kg H_2SO_4/t
Maximum potential acidity	MPA	7.3	kg H_2SO_4/t
ANC/MPA ratio		2.3	
Net acid producing potential	NAPP	-9.7	kg H_2SO_4/t

NET ACID GENERATION

pH after oxidation	NAG_{pH}	5.0	(pH)
Net acid generation to pH 4.5	$NAG_{4.5}$	<0.1	kg H_2SO_4/t
Net acid generation to pH 7.0	$NAG_{7.0}$	1	kg H_2SO_4/t
Net acid generation, pH 4.5 to pH 7.0		1	kg H_2SO_4/t

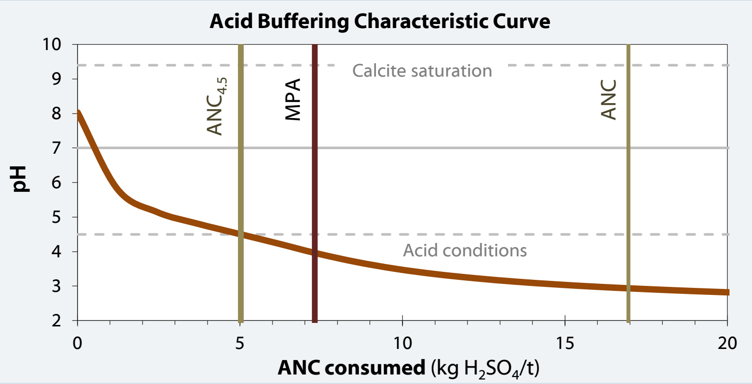
RISK CLASSIFICATION*

AMD Risk	**Unlikely to be acid generating**
NMD Risk	Low potential for NMD generation
Salinity Risk	Low potential for salinity generation

*Determined from static geochemistry

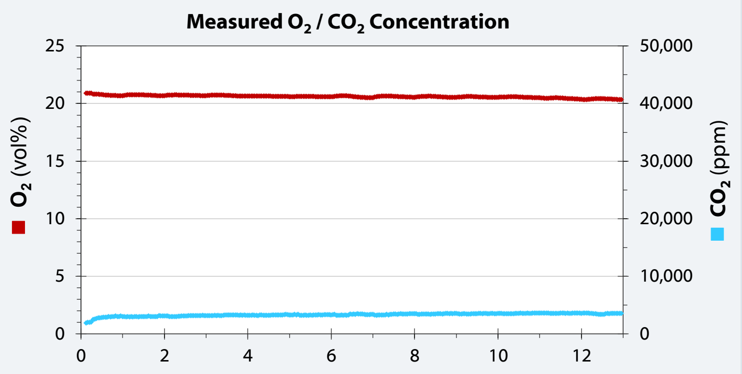
ACID NEUTRALISATION EFFICIENCY

Acid neutralisation capacity to pH 4.5	$ANC_{4.5}$	5.0	kg H_2SO_4/t
Acid conditions (MPA > $ANC_{4.5}$)		Possible	



KINETIC GEOCHEMISTRY

OXYGEN CONSUMPTION TESTWORK



Temp: 25 °C

Logging interval: 1 hr

Sample mass (dry)	3.46 kg	GMC*	1.0 wt% H_2O

*Gravimetric moisture content

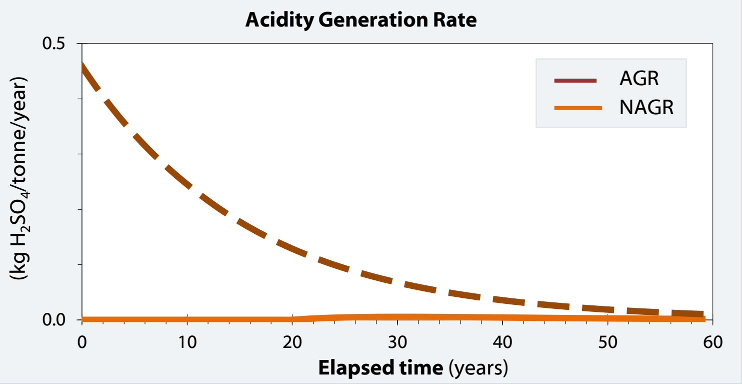
PYRITE OXIDATION RATE

Oxygen consumption rate	OCR	0.024	mmol/kg/day
Pyrite oxidation rate*	POR	6.2	wt% Pyr/yr
POR (intrinsic units)		8.9	$\times 10^{-9}$ kg O_2/t/s
		0.1	kg S/t/yr
Acidity generation rate (intrinsic)	AGR	0.5	kg H_2SO_4/t/yr

*Normalised to sample pyrite content (ie., fraction of pyrite oxidised per year)

NET ACID GENERATION RATE

Initial net acid generation rate	NAGR	<0.1	kg H_2SO_4/t/yr
Estimated lag time to onset of acid conditions		20	years
Estimated peak NAGR (at ~30 years)		0.01	kg H_2SO_4/t/yr
Estimated half-life of reactive sulfide		12	years
Estimated longevity of sulfide oxidation		60	years



TEST REPORT

MAJOR AND TRACE ELEMENT CHEMISTRY

Element	Symbol	SAMPLE SOLIDS	NAG LEACHATE mg/kg solids	OXCON LEACHATE mg/L
Calcium	Ca	wt%		<1
Magnesium	Mg	wt%		1.00
Potassium	K	wt%		2.00
Sodium	Na	wt%		10.0
Chloride	Cl	mg/kg		8.00
Fluoride	F	0.9 mg/kg		0.9
Carbon	C	0.20760968 wt%		
Sulfur/sulfate	S/SO_4	0.27 wt%		14.0
Aluminium	Al	wt%		0.08
Iron	Fe	wt%		0.09
Manganese	Mn	mg/kg		0.005
Phosphorus	P	mg/kg		<0.01
Antimony	Sb	<0.001 mg/kg		<0.001
Arsenic	As	<0.001 mg/kg		<0.001
Barium	Ba	mg/kg		
Beryllium	Be	mg/kg		
Bismuth	Bi	<0.001 mg/kg		<0.001
Boron	B	0.22 mg/kg		0.22
Cadmium	Cd	<0.0001 mg/kg		<0.0001
Caesium	Cs	mg/kg		
Cerium	Ce	mg/kg		
Chromium	Cr	<0.001 mg/kg		<0.001
Cobalt	Co	<0.001 mg/kg		<0.001
Copper	Cu	0.003 mg/kg		0.003
Gallium	Ga	mg/kg		
Germanium	Ge	mg/kg		
Hafnium	Hf	mg/kg		
Indium	In	mg/kg		
Lanthanum	La	mg/kg		
Lead	Pb	<0.001 mg/kg		<0.001
Lithium	Li	mg/kg		
Mercury	Hg	<0.0001 mg/kg		<0.0001
Molybdenum	Mo	0.002 mg/kg		0.002
Nickel	Ni	<0.001 mg/kg		<0.001
Niobium	Nb	mg/kg		
Rubidium	Rb	mg/kg		
Selenium	Se	<0.01 mg/kg		<0.01
Silver	Ag	<0.001 mg/kg		<0.001
Strontium	Sr	mg/kg		
Tellurium	Te	<0.005 mg/kg		<0.005
Thallium	Tl	<0.001 mg/kg		<0.001
Thorium	Th	mg/kg		
Tin	Sn	<0.001 mg/kg		<0.001
Titanium	Ti	mg/kg		
Tungsten	W	mg/kg		
Uranium	U	<0.001 mg/kg		<0.001
Vanadium	V	<0.01 mg/kg		<0.01
Yttrium	Y	mg/kg		
Zinc	Zn	<0.005 mg/kg		<0.005
Zirconium	Zr	mg/kg		

OXCON LEACHATE – GENERAL PARAMETERS

pH	6.8
Electrical conductivity (EC)	0.07 mS/cm
Alkalinity	4.0 mg/L $CaCO_3$
Acidity – measured	3.0 mg/L $CaCO_3$
Acidity – calculated[1]	<5 mg/L $CaCO_3$
POR based on sulfate release[2]	1.2 wt% Pyr/yr

[1] Calculated from metal content.

[2] Strongly influenced by sample storage history.

MINERALOGY

Mineral	wt%
Albite	71.0
Chlorite	14.6
Biotite	5.5
Quartz	3.3
Muscovite	2.2
Hematite	2.1
Ankerite	0.4
Serpentine	0.4
Pyrite	0.4
TOTAL	99.9

Mineralogy determined by X-ray diffraction (XRD) analysis.

SAMPLE AS TESTED

CHEMISTRY NOTES

Chemical abundance index (CAI)	Low	Medium	High
Sample solids	CAI based on the geochemical abundance index of enrichment relative to average global crustal abundance.		
NAG leachate	CAI based on the leachable chemical content and the solids CAI.		
OxCon leachate	CAI based on the chemical enrichment in reference to ANZECC (2000) guideline levels for 99% aquatic ecosystem protection.		

All chemical analyses were conducted by NATA-accredited laboratories.

Ver. 7.10

TEST REPORT

SAMPLE DETAILS

Date	13 September 2013
Sample ID	NGS015-008K
Sample Description	Black shale (footwall) waste rock

Prepared for	Eastern Iron Limited
Project	Nowa Nowa Iron Ore Project
Particle size	−20 mm
Reference lithology	Shale

SUMMARY OF SAMPLE ENVIRONMENTAL BEHAVIOUR

AMD/NMD/salinity risk	Moderate/high potential for acid generation
Longevity of sulfide oxidation	Sulfide oxidation (primary acidity generation and water quality impacts) expected to persist for ~250 years
Predicted water quality impacts	NMD expected initially, onset of acid conditions expected after ~2 years, peak acid generation at ~23 years
Leachate components of concern	Cobalt, nickel
Key reactive minerals	Pyrite, ankerite

STATIC GEOCHEMISTRY

SULFUR SPECIATION

Total sulfur	1.3	wt% S
Readily soluble acid-forming sulfate sulfur	<0.02	wt% S
Readily soluble non-acid-forming sulfate sulfur	–	wt% S
Sparingly soluble acid-forming sulfate sulfur	–	wt% S
Sulfide sulfur	1.1	wt% S
Equivalent pyrite content	2.1	wt% FeS_2

ACID–BASE ACCOUNTING

Acid neutralising capacity	ANC	7.1	kg H_2SO_4/t
Maximum potential acidity	MPA	33.6	kg H_2SO_4/t
ANC/MPA ratio		0.2	
Net acid producing potential	NAPP	26.5	kg H_2SO_4/t

NET ACID GENERATION

pH after oxidation	NAG_{pH}	2.8	(pH)
Net acid generation to pH 4.5	$NAG_{4.5}$	28	kg H_2SO_4/t
Net acid generation to pH 7.0	$NAG_{7.0}$	36	kg H_2SO_4/t
Net acid generation, pH 4.5 to pH 7.0		8	kg H_2SO_4/t

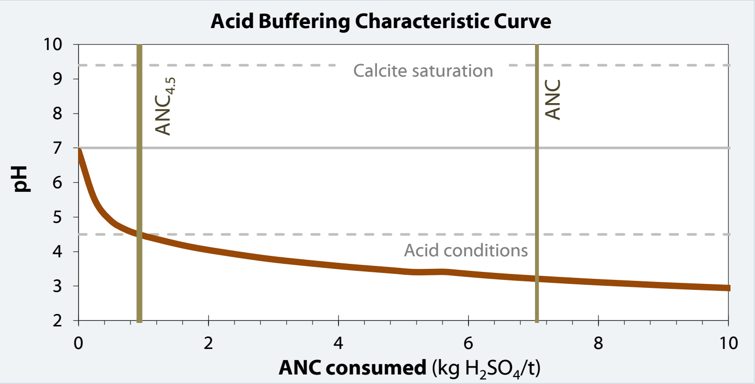
RISK CLASSIFICATION*

AMD Risk	**Moderate/high potential for acid generation**
NMD Risk	Moderate potential for NMD generation
Salinity Risk	Moderate potential for salinity generation

*Determined from static geochemistry

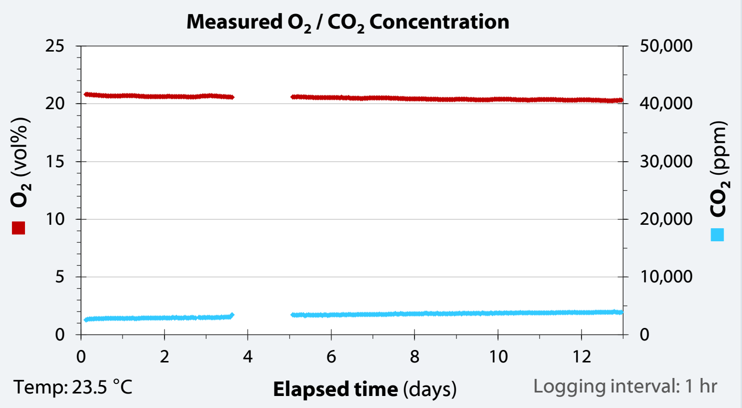
ACID NEUTRALISATION EFFICIENCY

Acid neutralisation capacity to pH 4.5	$ANC_{4.5}$	0.9	kg H_2SO_4/t
Acid conditions (MPA > $ANC_{4.5}$)		Highly likely	



KINETIC GEOCHEMISTRY

OXYGEN CONSUMPTION TESTWORK



Sample mass (dry)	3.91 kg	GMC*	1.0 wt% H_2O

*Gravimetric moisture content

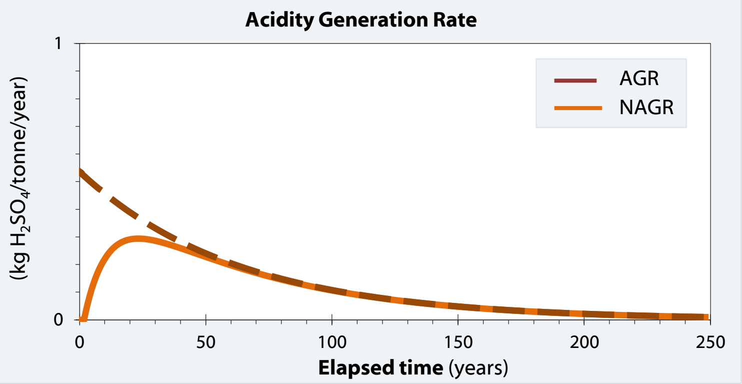
PYRITE OXIDATION RATE

Oxygen consumption rate	OCR	0.028	mmol/kg/day
Pyrite oxidation rate*	POR	1.6	wt% Pyr/yr
POR (intrinsic units)		10 0.2	$\times 10^{-9}$ kg O_2/t/s kg S/t/yr
Acidity generation rate (intrinsic)	AGR	0.5	kg H_2SO_4/t/yr

*Normalised to sample pyrite content (ie., fraction of pyrite oxidised per year)

NET ACID GENERATION RATE

Initial net acid generation rate	NAGR	<0.1	kg H_2SO_4/t/yr
Estimated lag time to onset of acid conditions		2	years
Estimated peak NAGR (at ~23 years)		0.29	kg H_2SO_4/t/yr
Estimated half-life of reactive sulfide		44	years
Estimated longevity of sulfide oxidation		250	years



TEST REPORT

MAJOR AND TRACE ELEMENT CHEMISTRY

Element	Symbol	SAMPLE SOLIDS		NAG LEACHATE	OXCON LEACHATE
				mg/kg solids	mg/L
Calcium	Ca	–	wt%	–	7.00
Magnesium	Mg	–	wt%	–	14.0
Potassium	K	–	wt%	–	3.00
Sodium	Na	–	wt%	–	57.0
Chloride	Cl	–	mg/kg	–	117
Fluoride	F	0.2	mg/kg	–	0.2
Carbon	C	0.08640403	wt%	–	–
Sulfur/sulfate	S/SO_4	1.33	wt%	–	46.0
Aluminium	Al	–	wt%	–	0.14
Iron	Fe	–	wt%	–	0.31
Manganese	Mn	–	mg/kg	–	0.066
Phosphorus	P	–	mg/kg	–	<0.01
Antimony	Sb	<0.001	mg/kg	–	<0.001
Arsenic	As	0.001	mg/kg	–	0.001
Barium	Ba	–	mg/kg	–	–
Beryllium	Be	–	mg/kg	–	–
Bismuth	Bi	<0.001	mg/kg	–	<0.001
Boron	B	0.13	mg/kg	–	0.13
Cadmium	Cd	<0.0001	mg/kg	–	<0.0001
Caesium	Cs	–	mg/kg	–	–
Cerium	Ce	–	mg/kg	–	–
Chromium	Cr	<0.001	mg/kg	–	<0.001
Cobalt	Co	0.054	mg/kg	–	0.054
Copper	Cu	0.006	mg/kg	–	0.006
Gallium	Ga	–	mg/kg	–	–
Germanium	Ge	–	mg/kg	–	–
Hafnium	Hf	–	mg/kg	–	–
Indium	In	–	mg/kg	–	–
Lanthanum	La	–	mg/kg	–	–
Lead	Pb	0.003	mg/kg	–	0.003
Lithium	Li	–	mg/kg	–	–
Mercury	Hg	<0.0001	mg/kg	–	<0.0001
Molybdenum	Mo	0.002	mg/kg	–	0.002
Nickel	Ni	0.298	mg/kg	–	0.298
Niobium	Nb	–	mg/kg	–	–
Rubidium	Rb	–	mg/kg	–	–
Selenium	Se	0.01	mg/kg	–	0.01
Silver	Ag	<0.001	mg/kg	–	<0.001
Strontium	Sr	–	mg/kg	–	–
Tellurium	Te	<0.005	mg/kg	–	<0.005
Thallium	Tl	<0.001	mg/kg	–	<0.001
Thorium	Th	–	mg/kg	–	–
Tin	Sn	<0.001	mg/kg	–	<0.001
Titanium	Ti	–	mg/kg	–	–
Tungsten	W	–	mg/kg	–	–
Uranium	U	0.006	mg/kg	–	0.006
Vanadium	V	<0.01	mg/kg	–	<0.01
Yttrium	Y	–	mg/kg	–	–
Zinc	Zn	0.029	mg/kg	–	0.029
Zirconium	Zr	–	mg/kg	–	–

OXCON LEACHATE – GENERAL PARAMETERS

pH	5.5	
Electrical conductivity (EC)	0.48	mS/cm
Alkalinity	<1	mg/L $CaCO_3$
Acidity – measured	5.0	mg/L $CaCO_3$
Acidity – calculated[1]	<5	mg/L $CaCO_3$
POR based on sulfate release[2]	0.3	wt% Pyr/yr

[1] Calculated from metal content.

[2] Strongly influenced by sample storage history.

MINERALOGY

Mineral	wt%
Quartz	67.0
Muscovite	19.9
Chlorite	5.9
Biotite	2.4
Pyrite	1.9
Talc	1.5
Hematite	0.8
Albite	0.4
Ankerite	0.1
	0.0
	0.0
	0.0
	0.0
	0.0
TOTAL	99.9

Mineralogy determined by X-ray diffraction (XRD) analysis.

SAMPLE AS TESTED

CHEMISTRY NOTES

Chemical abundance index (CAI)	Low	Medium	High
Sample solids	CAI based on the geochemical abundance index of enrichment relative to average global crustal abundance.		
NAG leachate	CAI based on the leachable chemical content and the solids CAI.		
OxCon leachate	CAI based on the chemical enrichment in reference to ANZECC (2000) guideline levels for 99% aquatic ecosystem protection.		

All chemical analyses were conducted by NATA-accredited laboratories.

Ver. 7.10

OxCon

Oxygen consumption test

EARTH SYSTEMS
ANALYTICAL

TEST REPORT

SAMPLE DETAILS

Date	13 September 2013
Sample ID	ROM ore (simulated)
Sample Description	ROM ore based on wet LIMS tails kinetic geochemistry and calculated average composition

Prepared for	Eastern Iron Limited
Project	Nowa Nowa Iron Project
Particle size	−10 mm
Reference lithology	Ore

SUMMARY OF SAMPLE ENVIRONMENTAL BEHAVIOUR

AMD/NMD/salinity risk	Moderate/high potential for acid generation
Longevity of sulfide oxidation	Sulfide oxidation (primary acidity generation and water quality impacts) expected to persist for ~200 years
Predicted water quality impacts	NMD expected initially, onset of acid conditions expected after ~2 years, peak acid generation at ~20 years
Leachate components of concern	N/A
Key reactive minerals	N/A

STATIC GEOCHEMISTRY

SULFUR SPECIATION

Total sulfur	2.0	wt% S
Readily soluble acid-forming sulfate sulfur	<0.02	wt% S
Readily soluble non-acid-forming sulfate sulfur	0.03	wt% S
Sparingly soluble acid-forming sulfate sulfur	<0.01	wt% S
Sulfide sulfur	2.0	wt% S
Equivalent pyrite content	3.8	wt% FeS_2

ACID–BASE ACCOUNTING

Acid neutralising capacity	ANC	18.3	kg H_2SO_4/t
Maximum potential acidity	MPA	62.0	kg H_2SO_4/t
ANC/MPA ratio		0.3	
Net acid producing potential	NAPP	+44	kg H_2SO_4/t

NET ACID GENERATION

pH after oxidation	NAG_{pH}	–	(pH)
Net acid generation to pH 4.5	$NAG_{4.5}$	–	kg H_2SO_4/t
Net acid generation to pH 7.0	$NAG_{7.0}$	–	kg H_2SO_4/t
Net acid generation, pH 4.5 to pH 7.0		<0.1	kg H_2SO_4/t

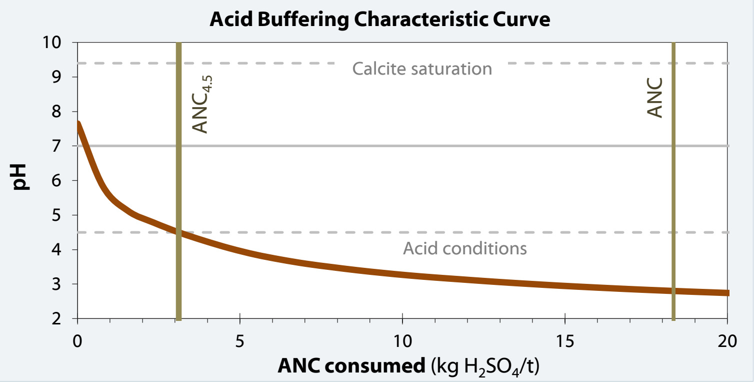
RISK CLASSIFICATION*

AMD Risk	**Moderate/high potential for acid generation**
NMD Risk	High potential for NMD generation
Salinity Risk	High potential for salinity generation

*Determined from static geochemistry

ACID NEUTRALISATION EFFICIENCY

Acid neutralisation capacity to pH 4.5	$ANC_{4.5}$	3.1	kg H_2SO_4/t
Acid conditions (MPA > $ANC_{4.5}$)		Highly likely	



KINETIC GEOCHEMISTRY

OXYGEN CONSUMPTION TESTWORK

Simulation
(no testwork conducted)

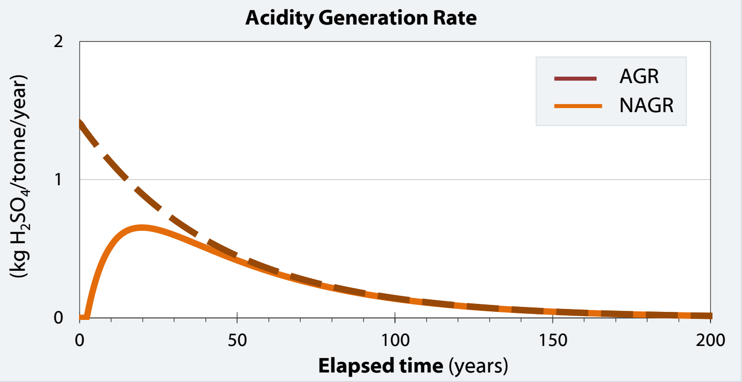
PYRITE OXIDATION RATE

Oxygen consumption rate	OCR	0.074	mmol/kg/day
Pyrite oxidation rate*	POR	2.3	wt% Pyr/yr
POR (intrinsic units)		27	$\times 10^{-9}$ kg O_2/t/s
		0.5	kg S/t/yr
Acidity generation rate (intrinsic)	AGR	1.4	kg H_2SO_4/t/yr

*Normalised to sample pyrite content (ie., fraction of pyrite oxidised per year)

NET ACID GENERATION RATE

Initial net acid generation rate	NAGR	<0.1	kg H_2SO_4/t/yr
Estimated lag time to onset of acid conditions		2	years
Estimated peak NAGR (at ~20 years)		0.65	kg H_2SO_4/t/yr
Estimated half-life of reactive sulfide		30	years
Estimated longevity of sulfide oxidation		200	years



OxCon

Oxygen consumption test

EARTH SYSTEMS
ANALYTICAL

TEST REPORT

SAMPLE DETAILS

Date	13 September 2013	Prepared for	Eastern Iron Limited
Sample ID	Dry LIMS product (simulated)	Project	Nowa Nowa Iron Project
Sample Description	Dry LIMS product based on wet LIMS tails kinetic geochemistry and calculated product composition	Particle size	−10 mm
		Reference lithology	Ore product

SUMMARY OF SAMPLE ENVIRONMENTAL BEHAVIOUR

AMD/NMD/salinity risk	Moderate potential for acid generation
Longevity of sulfide oxidation	Sulfide oxidation (primary acidity generation and water quality impacts) expected to persist for ~200 years
Predicted water quality impacts	NMD expected initially, onset of acid conditions expected after ~3 years, peak acid generation at ~23 years
Leachate components of concern	N/A
Key reactive minerals	N/A

STATIC GEOCHEMISTRY

SULFUR SPECIATION

Total sulfur		1.5	wt% S
Readily soluble acid-forming sulfate sulfur		<0.02	wt% S
Readily soluble non-acid-forming sulfate sulfur		0.03	wt% S
Sparingly soluble acid-forming sulfate sulfur		<0.01	wt% S
Sulfide sulfur		1.5	wt% S
Equivalent pyrite content		2.8	wt% FeS_2

ACID–BASE ACCOUNTING

Acid neutralising capacity	ANC	18.3	kg H_2SO_4/t
Maximum potential acidity	MPA	45.8	kg H_2SO_4/t
ANC/MPA ratio		0.4	
Net acid producing potential	NAPP	+27	kg H_2SO_4/t

NET ACID GENERATION

pH after oxidation	NAG_{pH}	–	(pH)
Net acid generation to pH 4.5	$NAG_{4.5}$	–	kg H_2SO_4/t
Net acid generation to pH 7.0	$NAG_{7.0}$	–	kg H_2SO_4/t
Net acid generation, pH 4.5 to pH 7.0		<0.1	kg H_2SO_4/t

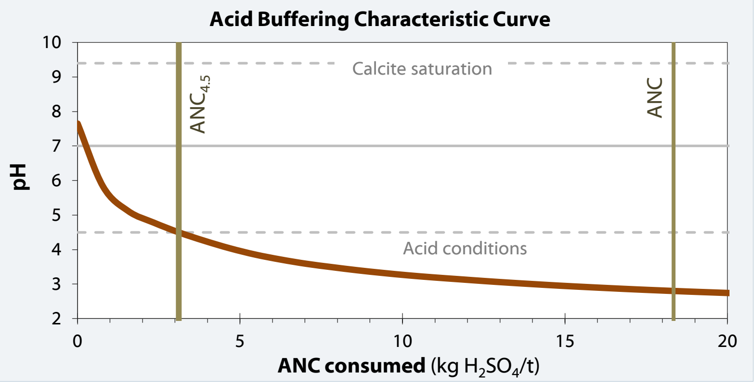
RISK CLASSIFICATION*

AMD Risk	**Moderate potential for acid generation**
NMD Risk	Moderate potential for NMD generation
Salinity Risk	Moderate potential for salinity generation

*Determined from static geochemistry

ACID NEUTRALISATION EFFICIENCY

Acid neutralisation capacity to pH 4.5	$ANC_{4.5}$	3.1	kg H_2SO_4/t
Acid conditions (MPA > $ANC_{4.5}$)		Highly likely	



Acid Buffering Characteristic Curve

KINETIC GEOCHEMISTRY

OXYGEN CONSUMPTION TESTWORK

Simulation
(no testwork conducted)

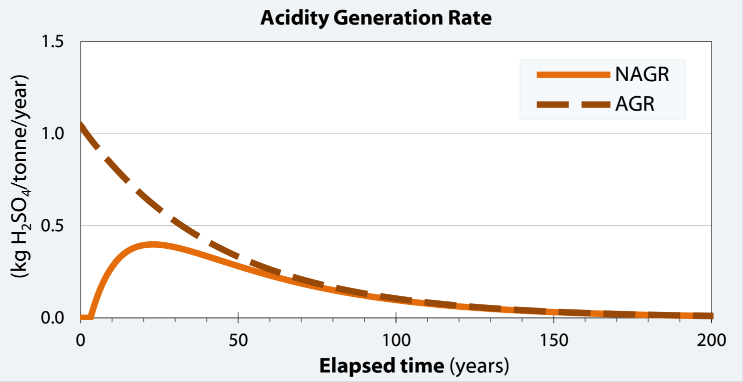
PYRITE OXIDATION RATE

Oxygen consumption rate	OCR	0.055	mmol/kg/day
Pyrite oxidation rate*	POR	2.3	wt% Pyr/yr
POR (intrinsic units)		20	$\times 10^{-9}$ kg O_2/t/s
		0.3	kg S/t/yr
Acidity generation rate (intrinsic)	AGR	1.0	kg H_2SO_4/t/yr

*Normalised to sample pyrite content (ie., fraction of pyrite oxidised per year)

NET ACID GENERATION RATE

Initial net acid generation rate	NAGR	<0.1	kg H_2SO_4/t/yr
Estimated lag time to onset of acid conditions		3	years
Estimated peak NAGR (at ~23 years)		0.40	kg H_2SO_4/t/yr
Estimated half-life of reactive sulfide		30	years
Estimated longevity of sulfide oxidation		200	years



Acidity Generation Rate

TEST REPORT

SAMPLE DETAILS

Date	13 September 2013	Prepared for	Eastern Iron Limited
Sample ID	Low-grade ore (simulated)	Project	Nowa Nowa Iron Project
Sample Description	Low-grade ore based on wet LIMS tails kinetic geochemistry and calculated average composition	Particle size	−10 mm
		Reference lithology	Low-grade ore

SUMMARY OF SAMPLE ENVIRONMENTAL BEHAVIOUR

AMD/NMD/salinity risk	High potential for acid generation
Longevity of sulfide oxidation	Sulfide oxidation (primary acidity generation and water quality impacts) expected to persist for ~200 years
Predicted water quality impacts	NMD expected initially, onset of acid conditions expected after ~1 years, peak acid generation at ~13 years
Leachate components of concern	N/A
Key reactive minerals	N/A

STATIC GEOCHEMISTRY

SULFUR SPECIATION

Total sulfur	4.1	wt% S
Readily soluble acid-forming sulfate sulfur	<0.02	wt% S
Readily soluble non-acid-forming sulfate sulfur	0.03	wt% S
Sparingly soluble acid-forming sulfate sulfur	<0.01	wt% S
Sulfide sulfur	4.1	wt% S
Equivalent pyrite content	7.7	wt% FeS_2

ACID–BASE ACCOUNTING

Acid neutralising capacity	ANC	18.3	kg H_2SO_4/t
Maximum potential acidity	MPA	125	kg H_2SO_4/t
ANC/MPA ratio		0.1	
Net acid producing potential	NAPP	+107	kg H_2SO_4/t

NET ACID GENERATION

pH after oxidation	NAG_{pH}	–	(pH)
Net acid generation to pH 4.5	$NAG_{4.5}$	–	kg H_2SO_4/t
Net acid generation to pH 7.0	$NAG_{7.0}$	–	kg H_2SO_4/t
Net acid generation, pH 4.5 to pH 7.0		<0.1	kg H_2SO_4/t

RISK CLASSIFICATION*

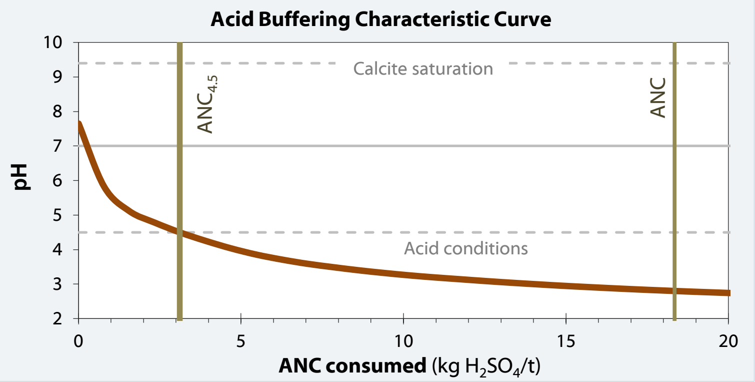
AMD Risk	**High potential for acid generation**
NMD Risk	High potential for NMD generation
Salinity Risk	High potential for salinity generation

*Determined from static geochemistry

ACID NEUTRALISATION EFFICIENCY

Acid neutralisation capacity to pH 4.5	$ANC_{4.5}$	3.1	kg H_2SO_4/t
Acid conditions (MPA > $ANC_{4.5}$)	Highly likely		

Acid Buffering Characteristic Curve



KINETIC GEOCHEMISTRY

OXYGEN CONSUMPTION TESTWORK

Simulation
(no testwork conducted)

PYRITE OXIDATION RATE

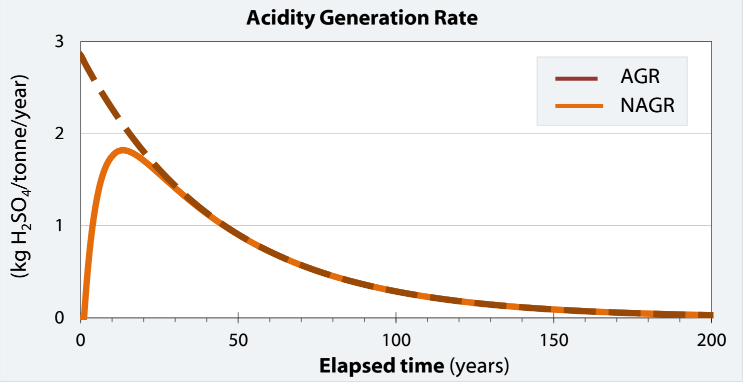
Oxygen consumption rate	OCR	0.15	mmol/kg/day
Pyrite oxidation rate*	POR	2.3	wt% Pyr/yr
POR (intrinsic units)		55	$\times 10^{-9}$ kg O_2/t/s
		0.9	kg S/t/yr
Acidity generation rate (intrinsic)	AGR	2.8	kg H_2SO_4/t/yr

*Normalised to sample pyrite content (ie., fraction of pyrite oxidised per year)

NET ACID GENERATION RATE

Initial net acid generation rate	NAGR	<0.1	kg H_2SO_4/t/yr
Estimated lag time to onset of acid conditions		1	years
Estimated peak NAGR (at ~13 years)		1.8	kg H_2SO_4/t/yr
Estimated half-life of reactive sulfide		30	years
Estimated longevity of sulfide oxidation		200	years

Acidity Generation Rate



TEST REPORT

SAMPLE DETAILS

Date	13 September 2013	Prepared for	Eastern Iron Limited
Sample ID	Felsice volcanics (simulated)	Project	Nowa Nowa Iron Ore Project
Sample Description	Simulated felsic volcanics (hanging wall) waste rock based on results for NGS017-005	Particle size	–20 mm
		Reference lithology	Felsic volcanics

SUMMARY OF SAMPLE ENVIRONMENTAL BEHAVIOUR

AMD/NMD/salinity risk	Unlikely to be acid generating
Longevity of sulfide oxidation	Sulfide oxidation (primary acidity generation and water quality impacts) expected to persist for ~60 years
Predicted water quality impacts	Minor NMD possible, acid conditions not expected in the long term
Leachate components of concern	N/A
Key reactive minerals	N/A

STATIC GEOCHEMISTRY

SULFUR SPECIATION

Total sulfur	0.07	wt% S
Readily soluble acid-forming sulfate sulfur	<0.02	wt% S
Readily soluble non-acid-forming sulfate sulfur	–	wt% S
Sparingly soluble acid-forming sulfate sulfur	–	wt% S
Sulfide sulfur	0.07	wt% S
Equivalent pyrite content	0.13	wt% FeS_2

ACID–BASE ACCOUNTING

Acid neutralising capacity	ANC	15.0	kg H_2SO_4/t
Maximum potential acidity	MPA	2.1	kg H_2SO_4/t
ANC/MPA ratio		7.1	
Net acid producing potential	NAPP	–13	kg H_2SO_4/t

NET ACID GENERATION

pH after oxidation	NAG_{pH}	–	(pH)
Net acid generation to pH 4.5	$NAG_{4.5}$	–	kg H_2SO_4/t
Net acid generation to pH 7.0	$NAG_{7.0}$	–	kg H_2SO_4/t
Net acid generation, pH 4.5 to pH 7.0		<0.1	kg H_2SO_4/t

RISK CLASSIFICATION*

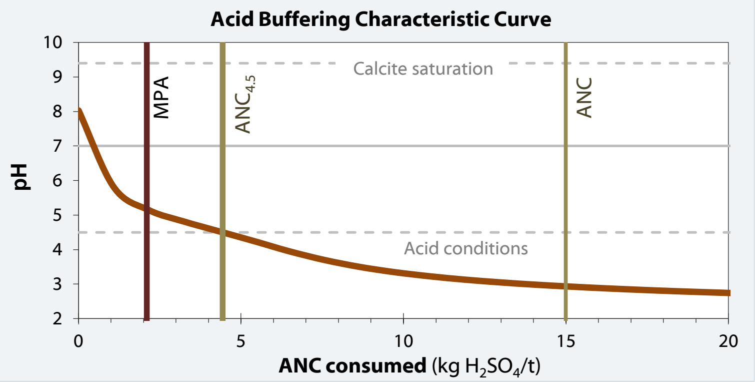
AMD Risk	**Unlikely to be acid generating**
NMD Risk	Unlikely to generate NMD
Salinity Risk	Unlikely to be salinity generating

*Determined from static geochemistry

ACID NEUTRALISATION EFFICIENCY

Acid neutralisation capacity to pH 4.5	$ANC_{4.5}$	4.4	kg H_2SO_4/t
Acid conditions (MPA > $ANC_{4.5}$)		Very unlikely	

Acid Buffering Characteristic Curve



KINETIC GEOCHEMISTRY

OXYGEN CONSUMPTION TESTWORK

Simulation
(no testwork conducted)

PYRITE OXIDATION RATE

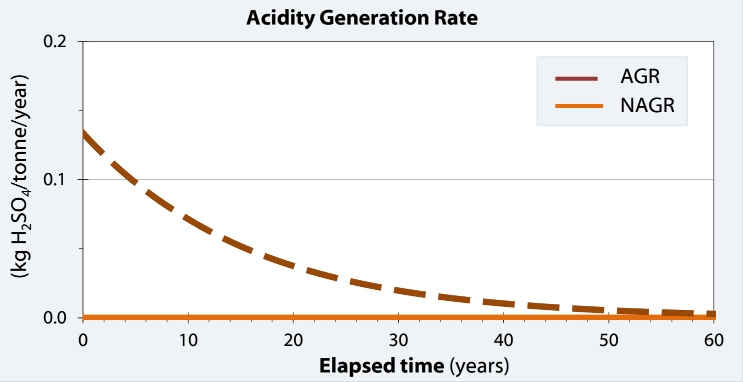
Oxygen consumption rate	OCR	0.003	mmol/kg/day
Pyrite oxidation rate*	POR	6.2	wt% Pyr/yr
POR (intrinsic units)		0.94	$\times 10^{-9}$ kg O_2/t/s
		0.02	kg S/t/yr
Acidity generation rate (intrinsic)	AGR	0.13	kg H_2SO_4/t/yr

*Normalised to sample pyrite content (ie., fraction of pyrite oxidised per year)

NET ACID GENERATION RATE

Initial net acid generation rate	NAGR	<0.1	kg H_2SO_4/t/yr
Estimated lag time to onset of acid conditions		N/A	
Estimated peak NAGR		<0.01	kg H_2SO_4/t/yr
Estimated half-life of reactive sulfide		10	years
Estimated longevity of sulfide oxidation		60	years

Acidity Generation Rate



TEST REPORT

SAMPLE DETAILS

Date	13 September 2013
Sample ID	Sediments (simulated)
Sample Description	Simulated sediment (footwall) waste rock based on results for NGS015-008K

Prepared for	Eastern Iron Limited
Project	Nowa Nowa Iron Ore Project
Particle size	–20 mm
Reference lithology	Shale

SUMMARY OF SAMPLE ENVIRONMENTAL BEHAVIOUR

AMD/NMD/salinity risk	Low potential for acid generation
Longevity of sulfide oxidation	Sulfide oxidation (primary acidity generation and water quality impacts) expected to persist for ~250 years
Predicted water quality impacts	NMD expected initially, onset of acid conditions expected after ~30 years, peak acid generation at ~63 years
Leachate components of concern	N/A
Key reactive minerals	N/A

STATIC GEOCHEMISTRY

SULFUR SPECIATION

Total sulfur		0.82	wt% S
Readily soluble acid-forming sulfate sulfur		<0.02	wt% S
Readily soluble non-acid-forming sulfate sulfur		–	wt% S
Sparingly soluble acid-forming sulfate sulfur		–	wt% S
Sulfide sulfur		0.82	wt% S
Equivalent pyrite content		1.5	wt% FeS_2

ACID–BASE ACCOUNTING

Acid neutralising capacity	ANC	54.7	kg H_2SO_4/t
Maximum potential acidity	MPA	25.0	kg H_2SO_4/t
ANC/MPA ratio		2.2	
Net acid producing potential	NAPP	–30	kg H_2SO_4/t

NET ACID GENERATION

pH after oxidation	NAG_{pH}	–	(pH)
Net acid generation to pH 4.5	$NAG_{4.5}$	–	kg H_2SO_4/t
Net acid generation to pH 7.0	$NAG_{7.0}$	–	kg H_2SO_4/t
Net acid generation, pH 4.5 to pH 7.0		<0.1	kg H_2SO_4/t

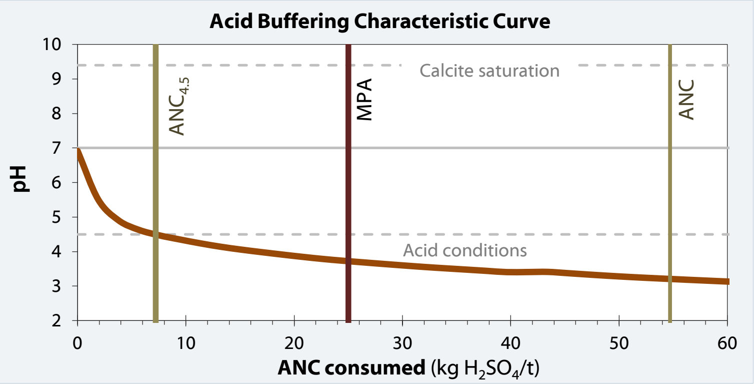
RISK CLASSIFICATION*

AMD Risk	Low potential for acid generation
NMD Risk	Moderate potential for NMD generation
Salinity Risk	Moderate potential for salinity generation

*Determined from static geochemistry

ACID NEUTRALISATION EFFICIENCY

Acid neutralisation capacity to pH 4.5	$ANC_{4.5}$	7.2	kg H_2SO_4/t
Acid conditions (MPA > $ANC_{4.5}$)		Likely	



KINETIC GEOCHEMISTRY

OXYGEN CONSUMPTION TESTWORK

Simulation
(no testwork conducted)

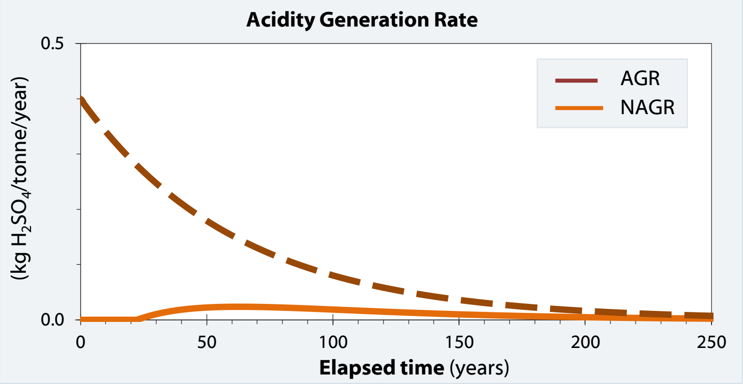
PYRITE OXIDATION RATE

Oxygen consumption rate	OCR	0.030	mmol/kg/day
Pyrite oxidation rate*	POR	1.6	wt% Pyr/yr
POR (intrinsic units)		11 0.19	$\times10^{-9}$ kg O_2/t/s kg S/t/yr
Acidity generation rate (intrinsic)	AGR	0.57	kg H_2SO_4/t/yr

*Normalised to sample pyrite content (ie., fraction of pyrite oxidised per year)

NET ACID GENERATION RATE

Initial net acid generation rate	NAGR	<0.1	kg H_2SO_4/t/yr
Estimated lag time to onset of acid conditions		30	years
Estimated peak NAGR (at ~63 years)		0.02	kg H_2SO_4/t/yr
Estimated half-life of reactive sulfide		40	years
Estimated longevity of sulfide oxidation		250	years



TEST METHOD AND TERMINOLOGY

OxCon is a laboratory-scale kinetic geochemical test for the estimation of sulfide oxidation rates, acidity generation rates and carbonate neutralisation rates for sulfidic geological materials.

The exposure of sulfide minerals, notably pyrite (FeS_2), to oxygen and water can result in acid and metalliferous drainage (AMD), also known as acid rock drainage (ARD). Prediction of the acidity generation potential of sulfidic materials is essential for AMD management and prevention, and is commonly determined through two types of analytical tests:

- *Static geochemical tests*. Measurement of sample composition to provide information on the maximum potential acidity and acid neutralisation capacity of a sample (including sulfur speciation, net acid generation (NAG), and acid–base accounting).
- *Kinetic geochemical tests*. Measurement of the actual acidity generation rate and carbonate neutralisation rate, providing information on the onset, magnitude and duration of acid generation and the potential for neutral metalliferous drainage (NMD) and saline drainage (SD).

The OxCon kinetic geochemical test allows for the fast, accurate and cost-effective determination of acidity generation rates. The OxCon method has the benefit of directly measuring the oxygen consumption associated with the pyrite oxidation reaction and carbon dioxide release during carbonate neutralisation.

As part of the OxCon test, a comprehensive suite of AMD-related sample characteristics are determined, including the net acidity generation rate (NAGR), the pyrite oxidation rate (POR) normalised to pyrite content, the time lag to onset of acid conditions, the longevity of sulfide oxidation, and the elements of concern in leachate. Using this information, high-risk materials can be identified and effective strategies for their long-term management can be developed.

Advantages of oxygen consumption testwork

Oxygen consumption techniques have a number of advantages relative to other laboratory-scale kinetic geochemical tests such as column leach and humidity cells tests, including:

- Rapid determination of oxidation rates (usually 1–8 weeks) compared with column leach and humidity cell tests (usually many months to years).
- The ability to quantify acid neutralisation efficiencies.
- Lower cost due to significantly lower analytical costs and shorter test durations.
- Greater accuracy. Direct measurement of oxygen consumption is more accurate than the inference of pyrite oxidation rates based on measurement of leachate sulfate flux (the basis for column leach and humidity cell tests). Leachate sulfate often includes unquantifiable contributions from the dissolution of secondary minerals present in the sample (which can lead to an overestimate of the pyrite oxidation rate) and/or the precipitation of secondary sulfate minerals (which would lead to an underestimate of the pyrite oxidation rate).
- Short test times allow for repeat runs for greater confidence or for testing the influence of variables such as moisture content (influencing oxygen diffusion), oxygen concentration, particle size distribution, carbonate content, sulfide content, sulfide mineralogy, bacterial inoculation, and temperature.
- Small sample size (typically 2–5 kg) and suitability for scaling to larger or smaller samples with relative ease.
- No need for multiple laboratory analyses during testwork, only initial acid–base accounting data and final leachate chemistry are required.
- Ability to test site AMD management strategies (eg. optimum water cover thickness or various waste rock dump designs).

Sample preparation

The preparation of samples for OxCon testing is specific to each project and the goals of analysis. The sample can be submitted for OxCon testing as-received, or can be modified or segregated for more detailed investigations. Additional preparation can include:

- Drying and rewetting to specific gravimetric moisture content
- Segregation by grain size
- Crushing to specific grain size
- Homogenisation
- Splitting to prepare multiple identical samples
- Insertion of a water cover
- Inoculation with bactericides
- Assessment of performance of cover systems
- Quantify oxygen diffusion rates through materials

An array of OxCon modules

Testwork procedure

Prior to the OxCon test, a subsample of the supplied material is submitted for a suite of analyses in order to characterise the sample with respect to its static geochemical properties, chemistry and mineralogy. The suite of analyses is tailored for each sample and may typically include:

- Major and trace element chemistry for geochemical abundance index (GAI) and lithological abundance index (LAI) assessments
- Gravimetric moisture content (GMC)
- Sulfur speciation
- Acid neutralising capacity (ANC)
- Net acid generation ($NAG_{4.5}$ and $NAG_{7.0}$) and oxidation pH (NAG_{pH})
- Mineralogy by x-ray diffraction (XRD)
- Carbon speciation
- Acid buffering characteristic curve
- NAG leache analysis (as required)

Testwork involves isolating a known mass of sulfide-bearing material in a known volume of oxygen inside a hermetically sealed vessel and allowing pyrite oxidation to proceed.

Once the test is initiated, oxygen in the vessel is consumed via pyrite oxidation (see Reaction 1 on page 3). Oxygen consumption is measured directly on an hourly basis and logged over the testwork period (eg. 1-8 weeks). Carbon dioxide may be generated as a result of carbonate neutralisation reactions (see Reaction 2 on page 3) and/or bacterial metabolism of organic carbon (for acid sulfate soils or coal samples). Carbon dioxide generation is measured hourly and logged.

Once the oxidation testwork is complete, the sample is flushed with deionized water at a ratio of 1:1 on a dry weight bases and the leachate analysed for the following parameters:

- pH and electrical conductivity ;
- Acidity and/or alkalinity (as appropriate);
- Major ion and dissolved metal concentrations.

The chemistry of the leachate provides information on key elements of concern and trace element leach rates (using trace element chemistry results), and provides an independent estimate of pyrite oxidation rates based on sulfate flux and acidity/alkalinity released from the sample by leaching.

Oxidation and neutralisation reactions

The OxCon test is designed to directly measure the rate of oxygen consumption associated with the oxidation of pyrite. On exposure to oxygen and water, pyrite oxidises to form iron oxyhydroxides and sulfuric acid (sulfate and acid) by the following reaction:

Reaction 1: Pyrite oxidation

$$\underset{\text{pyrite}}{FeS_2} + \underset{\text{oxygen}}{{}^{15}/_{4}\,O_2} + \underset{\text{water}}{{}^{7}/_{2}\,H_2O} \rightarrow \underset{\text{sulfate}}{2\,SO_4^{2-}} + \underset{\text{acid}}{4\,H^+} + \underset{\text{ferric hydroxide}}{Fe(OH)_3}$$

The acid produced by the oxidation of pyrite may subsequently be neutralised by carbonate minerals in the sample by the following reaction:

Reaction 2: Carbonate acid neutralisation

$$\underset{\text{sulfuric acid}}{H_2SO_4} + \underset{\text{calcium carbonate}}{CaCO_3} \rightarrow \underset{\text{calcium}}{Ca^{2+}} + \underset{\text{sulfate}}{SO_4^{2-}} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_{2\,(g)}\uparrow}$$

Interpreting OxCon data

The measured oxygen consumption rate (OCR) is proportional to the mass of pyrite in the sample (see Figure 1) and is converted into a pyrite oxidation rate (POR) using the stoichiometry of Reaction 1 and the sample pyrite content. In this way, the oxygen consumption rate is normalised to the sample pyrite content. The normalized POR is reported as a weight percentage of pyrite exposed to atmospheric oxygen that will be oxidised to ferric hydroxide ($Fe(OH)_3$) and sulfuric acid (H_2SO_4) per year (abbreviated as wt% FeS_2/yr). Normalising the oxygen consumption rate to the sample pyrite content allows comparison of results amongst different samples and different variables tested, and also allows results to be applied directly to predict pollution generation rates for materials of similar geology with variable pyrite contents.

The POR is also reported in commonly used units of kilograms of oxygen consumed per tonne of material per second (kg O_2/t/s), and kilograms of sulfur oxidised per tonne of material per year (kg S/t/yr). Unlike the POR given in units of wt% FeS_2/yr, these alternative units are not normalised with respect to pyrite content and are applicable only to the sample under test.

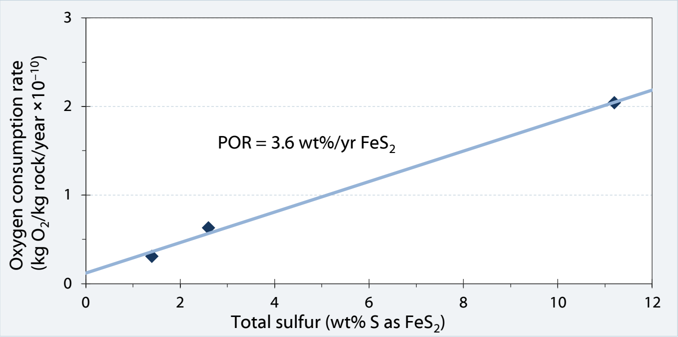


Figure 1: Example of the measured oxygen consumption rate (OCR) vs sample pyrite content for samples of the same rock with different sulfur contents. OCR is linearly related to sulfur content for different samples of the same rock type. The normalised pyrite oxidation rate (POR), in this case approximately 3.6 wt% FeS_2 per year, is an intrinsic property of the pyrite. Note that other sample physical properties such as particle size distribution and moisture content were constant in this example.

Applications of kinetic geochemical data

The primary application of kinetic geochemical data is to estimate the rate of pollution generation (acidity or salinity) from a waste material. Using the pyrite oxidation rate of a sulfidic material (normalized to the sulfur content, wt% FeS_2/yr) and the mass and average pyrite content of a bulk sulfidic waste material, it is possible to estimate the annual acidity generation rate of the material (kg H_2SO_4/t/yr).

For example, if 1 Mt of waste rock with an average pyrite content of 3 wt% FeS_2 and a pyrite oxidation rate of 0.5 wt% FeS_2/yr was exposed to atmospheric oxygen, the estimated acidity generation rate would be approximately 250 t H_2SO_4/yr for all the waste rock, or 0.25 kg of H_2SO_4 per tonne of waste rock each year. This information is vital for identifying high-risk materials and developing effective long-term AMD management or treatment strategies.

Pyrite oxidation rates obtained in the laboratory may vary considerably to those that occur in the environment due to a number of factors, including moisture content (which limits oxygen diffusion to reaction sites), particle size distribution (related to the surface area available to react with oxygen), sulfide mineral mineralogy, oxygen concentration, and temperature. The OxCon test can be used to develop relationships between the pyrite oxidation rate and one or more of these variables to enable more reliable estimates of real-world acidity generation rates. For example, pyrite oxidation rates can be determined for waste rock samples of various particle size fractions. These rates can be used with knowledge of the particle size distribution of waste rock on site to refine estimates of annual acidity generation rates.

Explanation of terms used in OxCon analytical reports

Physical parameters

Gravimetric moisture content (GMC): The relative mass of water in the tested sample, expressed as a percentage of the dry mass.

Sulfur speciation

Total sulfur: Total sample sulfur determined by Leco test.

Readily soluble acid-forming sulfate sulfur: A measure of sulfur present as minerals with relatively high solubility formed by prior oxidation of sulfide minerals and which release acid upon dissolution and oxidation (eg. melanterite).

Readily soluble non-acid-forming sulfate sulfur: A measure of sulfur present as relatively soluble minerals which do not contribute to acidity upon dissolution (eg. gypsum).

Sparingly soluble acid-forming sulfate sulfur: A measure of low solubility acidity storing sulfate minerals (eg. jarosite, alunite).

Sulfide sulfur: Sulfur in the form of sulfide minerals (eg. pyrite, pyrrhotite, chalcopyrite).

Equivalent pyrite content: The pyrite mass equivalent of sulfur, assuming all sulfur is present as pyrite.

Static geochemistry

Acid neutralising capacity (ANC): A measure of the potential acidity buffering capacity of the sample, typically due to the presence of calcium- and/or magnesium-bearing carbonate minerals. The ANC value assumes all of the carbonate material is available for acid neutralisation (kg H_2SO_4/t).

Maximum potential acidity (MPA): A calculation of the maximum amount of sulfuric acid (H_2SO_4) that could be produced if all sulfur in the sample (assumed to be sulfide) is oxidised. This is expressed in units of kilograms of H_2SO_4 equivalent per tonne of sample (kg H_2SO_4/t).

ANC/MPA: The ratio of a samples acid neutralising capacity to its maximum potential acidity, which provides an indication of a samples ability to neutralise any acidity generated.

Net acid production potential (NAPP): A measure of the overall acid-generating potential of the sample, calculated by subtracting the ANC value from MPA (kg H_2SO_4/t).

Net acid generation pH after oxidation (NAG_{pH}): The pH of a sample after oxidation with an excess of hydrogen peroxide.

Net acid generation to pH 4.5 ($NAG_{4.5}$): The equivalent acidity of a peroxide-oxidised sample titrated to pH 4.5 (kg H_2SO_4/t).

Net acid generation to pH 7.0 ($NAG_{7.0}$): The equivalent acidity of a peroxide-oxidised sample titrated to pH 7.0 (kg H_2SO_4/t).

AMD risk classification: The classification of a sample's potential AMD risk, based on static geochemical parameters.

NMD risk classification: The classification of a sample's potential NMD risk, based on static geochemical parameters.

Salinity risk classification: The classification of a sample's potential saline drainage risk, based on static geochemical parameters.

Pseudo-kinetic test results

Acid buffering characteristic curve (ABCC): The ABCC test involves incremental addition of acid to a sample to determine the behaviour of acid-neutralising minerals.

Acid neutralisation capacity to pH 4.5 ($ANE_{4.5}$): This parameter is determined from the ANC value corresponding to the point at which ABCC leachate becomes acidic based on the conventional definition (pH < 4.5). After the consumption of this amount of ANC by the neutralisation of acid (due to sulfide oxidation), the efficiency of acid neutralisation begins to taper and acid conditions may develop.

Acid conditions: A comparison of the maximum potential acidity (MPA) to the equivalent $ANC_{4.5}$ value. If MPA > $ANC_{4.5}$, acid conditions are likely to develop.

Major and trace element chemistry

Chemical abundance index (CAI): A factor of enrichment of an element relative to a reference concentration, expressed on a logarithmic scale. Geological materials are referenced to the average global crustal abundance (the global abundance index); leachates are referenced to ANZECC (2000) guidelines for aquatic ecosystem protection.

OxCon test results

Oxygen consumption rate (OCR): The rate of oxygen consumption due to pyrite oxidation in the sample as determined by the OxCon test, expressed in units of millimoles of oxygen gas (O_2) per kilogram of sample per day (mmol O_2/kg/day).

Pyrite oxidation and acidity generation rates

Pyrite oxidation rate (POR): The calculated rate of pyrite oxidation in the sample based on the measured OCR and equivalent pyrite content, expressed as a weight percentage of the available pyrite that oxidises each year (eg. a POR of 50 wt% FeS_2/yr indicates that half of the pyrite in the sample would be oxidised in one year). The POR does not take into account the effect of ANC or ANE (wt% FeS_2/yr).

Acidity generation rate (AGR): The rate of acidity generation by sulfide oxidation (kg H_2SO_4/t/yr). This rate is intrinsic to the tested sample and its sulfide content.

Net acidity generation rate (NAGR): An estimate of the net rate of acidity generation by the sample due to pyrite oxidation accounting for neutralisation by ANC.

Estimated lag time to onset of acid conditions: A measure of the initial delay before the development of acid drainage based on the cumulative acidity generation and $ANC_{4.5}$ value.

Estimated peak NAGR: After the onset of acid conditions, acid drainage generation will peak before tapering off as pyrite is consumed by oxidation. The lag time to peak net acid generation and the peak rate of acid generation are estimated from the NAGR evolution curve.

Estimated half-life of reactive sulfide: The estimated time (in years) for half of the available pyrite in the sample to oxidise based on the POR.

Indicative longevity of sulfide oxidation: The duration of sulfide oxidation processes (and hence primary acid generation and water quality impacts) based on the decay of pyrite by oxidation over time.

Leachate chemistry

Electrical conductivity (EC): A measure of the salinity of the leachate sample.

Alkalinity: For alkaline leachate, the calcium carbonate ($CaCO_3$) equivalent total alkalinity of the sample including hydroxide, carbonate and bicarbonate alkalinity.

Acidity – measured: For acidic leachate, the free acid and mineral acidity of the sample as measured by titration with sodium hydroxide to pH 8.3.

Acidity – calculated: The total acidity of the leachate calculated from the pH and the hydrolysis of metals using the ABATES acidity calculation tool.

POR based on sulfate release: Calculated as the equivalent mass of pyrite oxidised to produce the observed flux of sulfate in leachate, expressed as a weight percentage of the available pyrite that oxidises each year. Provides an independent (but less accurate) measure of pyrite oxidation during the OxCon test, and can be affected by the presence of sulfate salts in the sample.

Annex G

Laboratory reports

ALS Group

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EB1309889**
Client : **EASTERN IRON**
Contact : MR CHRIS HOSIE
Address : PO BOX
CROWS NEST New South Wales 1585
E-mail : chris.hosie@easterniron.com.au
Telephone : ----
Facsimile : ----
Project : NOWA NOWA
Order number : ----
C-O-C number : ----
Sampler : CHRIS HOSIE
Site : ----

Quote number : ----

Page : 1 of 10
Laboratory : Environmental Division Brisbane
Contact : Customer Services
Address : 2 Byth Street Stafford QLD Australia 4053
E-mail : Brisbane.Enviro.Services@alsglobal.com
Telephone : +61 7 3243 7222
Facsimile : +61 7 3243 7218
QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 23-APR-2013
Issue Date : 03-MAY-2013

No. of samples received : 22
No. of samples analysed : 18

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with
ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
SATISH.TRIVEDI	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**
- **ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.**

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)			*Client sample ID*	**N15-054**	**N15-020**	**N15-027**	**N16-071**	**N16-024**
			Client sampling date / time	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1309889-001**	**EB1309889-004**	**EB1309889-005**	**EB1309889-006**	**EB1309889-007**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-29.6**	**-2.8**	**83.7**	**71.5**	**2.5**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**6.8**	**6.6**	**2.4**	**2.4**	**4.8**
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	**60.8**	**48.7**	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	**0.1**	**0.1**	**64.2**	**56.7**	**1.1**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**38.2**	**6.2**	**8.7**	**6.5**	**6.4**
ANC as CaCO3	----	0.1	% CaCO3	**3.9**	**0.6**	**0.9**	**0.7**	**0.6**
Fizz Rating	----	0	Fizz Unit	**2**	**0**	**0**	**0**	**1**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**8.7**	**6.9**	**8.9**	**7.3**	**8.5**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.223**	<0.005	**2.09**	**1.89**	<0.005
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**139**	<10	**1300**	**1180**	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**2.08**	**0.64**	**0.44**	**0.67**	**0.64**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**417**	**129**	**88**	**134**	**129**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.67**	**0.21**	**0.14**	**0.21**	**0.21**
EA033-D: Retained Acidity								
KCl Extractable Sulfur (23Ce)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
HCl Extractable Sulfur (20Be)	----	0.02	% S	<0.02	**0.02**	<0.02	<0.02	**0.04**
Net Acid Soluble Sulfur (20Je)	----	0.02	% S	<0.02	**0.02**	<0.02	<0.02	**0.04**
acidity - Net Acid Soluble Sulfur (a-20J)	----	10	mole H+ / t	<10	<10	<10	<10	**16**
sulfidic - Net Acid Soluble Sulfur (s-20J)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	**0.03**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	**2.00**	**1.75**	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	**1250**	**1090**	<10

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)

			Client sample ID	**N15-054**	**N15-020**	**N15-027**	**N16-071**	**N16-024**
			Client sampling date / time	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1309889-001**	**EB1309889-004**	**EB1309889-005**	**EB1309889-006**	**EB1309889-007**
EA033-E: Acid Base Accounting - Continued								
Liming Rate	----	1	kg CaCO3/t	<1	<1	**94**	**82**	<1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.28**	**0.11**	**3.02**	**2.55**	**0.29**

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)			*Client sample ID*	**N16-047**	**N17-042**	**N19-044**	**N19-043**	**N19-051**
			Client sampling date / time	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1309889-008**	**EB1309889-009**	**EB1309889-010**	**EB1309889-011**	**EB1309889-012**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H_2SO_4/t	**-3.7**	**6.7**	**-229**	**-23.1**	**-26.1**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**3.6**	**3.6**	**10.1**	**6.0**	**3.2**
NAG (pH 4.5)	----	0.1	kg H_2SO_4/t	**1.7**	**1.9**	<0.1	<0.1	**5.7**
NAG (pH 7.0)	----	0.1	kg H_2SO_4/t	**5.1**	**11.1**	<0.1	**0.9**	**10.9**
EA013: Acid Neutralising Capacity								
ANC as H_2SO_4	----	0.5	kg H_2SO_4 equiv./t	**31.2**	**27.9**	**243**	**69.0**	**57.6**
ANC as $CaCO_3$	----	0.1	% $CaCO_3$	**3.2**	**2.8**	**24.8**	**7.0**	**5.9**
Fizz Rating	----	0	Fizz Unit	**2**	**1**	**3**	**2**	**2**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.7**	**9.7**	**9.3**	**8.5**	**8.4**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.630**	<0.005	**0.339**	**1.17**	**0.814**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**393**	<10	**211**	**732**	**507**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% $CaCO_3$	**2.33**	**2.21**	**25.1**	**4.87**	**2.71**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**465**	**441**	**5010**	**972**	**542**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.74**	**0.71**	**8.03**	**1.56**	**0.87**
EA033-D: Retained Acidity								
KCl Extractable Sulfur (23Ce)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
HCl Extractable Sulfur (20Be)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acid Soluble Sulfur (20Je)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Net Acid Soluble Sulfur (a-20J)	----	10	mole H+ / t	<10	<10	<10	<10	<10
sulfidic - Net Acid Soluble Sulfur (s-20J)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	**0.13**	<0.02	<0.02	**0.13**	**0.23**
Net Acidity (acidity units)	----	10	mole H+ / t	**83**	<10	<10	**84**	**146**

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)

			Client sample ID	N16-047	N17-042	N19-044	N19-043	N19-051
			Client sampling date / time	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]
Compound	CAS Number	LOR	Unit	EB1309889-008	EB1309889-009	EB1309889-010	EB1309889-011	EB1309889-012
EA033-E: Acid Base Accounting - Continued								
Liming Rate	----	1	kg CaCO3/t	**6**	<1	<1	**6**	**11**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.90**	**1.13**	**0.47**	**1.50**	**1.03**

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)			*Client sample ID*	**N19-054**	**N19-020**	**N19-030**	**N20-042**	**N20-016**
			Client sampling date / time	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1309889-013**	**EB1309889-014**	**EB1309889-015**	**EB1309889-018**	**EB1309889-019**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**20.3**	**25.7**	**-4.2**	**-910**	**-12.8**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**3.0**	**2.7**	**7.5**	**11.4**	**7.9**
NAG (pH 4.5)	----	0.1	kg H2SO4/t	**9.4**	**16.8**	<0.1	<0.1	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	**14.5**	**22.2**	<0.1	<0.1	<0.1
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**14.0**	**40.7**	**6.6**	**913**	**14.0**
ANC as CaCO3	----	0.1	% CaCO3	**1.4**	**4.2**	**0.7**	**93.1**	**1.4**
Fizz Rating	----	0	Fizz Unit	**1**	**2**	**0**	**5**	**1**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**6.6**	**9.5**	**8.5**	**9.8**	**8.6**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.853**	**0.943**	<0.005	**0.083**	<0.005
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**532**	**588**	<10	**52**	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**0.83**	**3.02**	**0.66**	**84.8**	**1.05**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**167**	**604**	**132**	**16900**	**209**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.27**	**0.97**	**0.21**	**27.2**	**0.34**
EA033-D: Retained Acidity								
KCl Extractable Sulfur (23Ce)	----	0.02	% S	<0.02	**0.14**	<0.02	<0.02	<0.02
HCl Extractable Sulfur (20Be)	----	0.02	% S	<0.02	**0.14**	<0.02	<0.02	<0.02
Net Acid Soluble Sulfur (20Je)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Net Acid Soluble Sulfur (a-20J)	----	10	mole H+ / t	<10	<10	<10	<10	<10
sulfidic - Net Acid Soluble Sulfur (s-20J)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	**0.67**	**0.30**	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	**421**	**185**	<10	<10	<10

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)			Client sample ID	**N19-054**	**N19-020**	**N19-030**	**N20-042**	**N20-016**
			Client sampling date / time	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]
Compound	CAS Number	LOR	Unit	**EB1309889-013**	**EB1309889-014**	**EB1309889-015**	**EB1309889-018**	**EB1309889-019**
EA033-E: Acid Base Accounting - Continued								
Liming Rate	----	1	kg CaCO3/t	**32**	**14**	<1	<1	<1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**1.12**	**2.17**	**0.08**	**0.10**	**0.04**

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)			*Client sample ID*	**N20-022**	**NGS015-006 COMPOSITE**	**NGS020-006 COMPOSITE**	----	----
			Client sampling date / time	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1309889-020**	**EB1309889-021**	**EB1309889-022**	**----**	**----**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-4.9**	**-2.8**	**-171**	----	----
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**7.8**	**3.6**	**10.8**	----	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	**1.9**	<0.1	----	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	**4.9**	<0.1	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**5.8**	**19.6**	**225**	----	----
ANC as CaCO3	----	0.1	% CaCO3	**0.6**	**2.0**	**22.9**	----	----
Fizz Rating	----	0	Fizz Unit	**0**	**1**	**3**	----	----
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.5**	**8.3**	**9.6**	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	<0.005	**0.392**	**1.39**	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**244**	**866**	----	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**0.64**	**6.20**	**6.20**	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**129**	**1240**	**1240**	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.21**	**1.98**	**1.98**	----	----
EA033-D: Retained Acidity								
KCl Extractable Sulfur (23Ce)	----	0.02	% S	<0.02	<0.02	**0.03**	----	----
HCl Extractable Sulfur (20Be)	----	0.02	% S	<0.02	<0.02	**0.02**	----	----
Net Acid Soluble Sulfur (20Je)	----	0.02	% S	<0.02	<0.02	<0.02	----	----
acidity - Net Acid Soluble Sulfur (a-20J)	----	10	mole H+ / t	<10	<10	<10	----	----
sulfidic - Net Acid Soluble Sulfur (s-20J)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	----	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	**0.06**	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	**41**	----	----

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)			*Client sample ID*	**N20-022**	**NGS015-006 COMPOSITE**	**NGS020-006 COMPOSITE**	----	----
			Client sampling date / time	[26-APR-2013]	[26-APR-2013]	[26-APR-2013]	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1309889-020**	**EB1309889-021**	**EB1309889-022**	**----**	**----**
EA033-E: Acid Base Accounting - Continued								
Liming Rate	----	1	kg CaCO3/t	<1	<1	**3**	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.03**	**0.55**	**1.76**	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB1310271**	Page	: 1 of 9
Client	: **EASTERN IRON**	Laboratory	: Environmental Division Brisbane
Contact	: MR CHRIS HOSIE	Contact	: Customer Services
Address	: PO BOX CROWS NEST New South Wales 1585	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: chris.hosie@easterniron.com.au	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: ----	Telephone	: +61 7 3243 7222
Facsimile	: ----	Facsimile	: +61 7 3243 7218
Project	: NOWA NOWA	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 30-APR-2013
Sampler	: CHRIS HOSIE	Issue Date	: 23-MAY-2013
Site	: ----		
		No. of samples received	: 29
Quote number	: ----	No. of samples analysed	: 29

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
SATISH.TRIVEDI	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils
Stephen Hislop	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**
- **ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.**
- **ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5**

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			*Client sample ID*	**NGS015-001K**	**NGS015-008K**	**NGS019-002K**	**NGS020-003K**	**NGS015-002**
			Client sampling date / time	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1310271-001**	**EB1310271-002**	**EB1310271-003**	**EB1310271-004**	**EB1310271-005**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-7.2**	**33.3**	**-6.3**	**-9.4**	**-7.7**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**7.0**	**2.8**	**7.2**	**7.3**	**6.6**
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	**28.4**	<0.1	<0.1	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	**36.3**	<0.1	<0.1	**13.7**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**7.2**	**7.4**	**7.2**	**9.4**	**8.9**
ANC as CaCO3	----	0.1	% CaCO3	**0.7**	**0.8**	**0.7**	**1.0**	**0.9**
Fizz Rating	----	0	Fizz Unit	**0**	**0**	**0**	**0**	**0**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**6.8**	**6.7**	**6.8**	**7.0**	**6.5**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	<0.005	**1.10**	<0.005	<0.005	**0.030**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**686**	<10	<10	**19**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**0.85**	**0.72**	**0.88**	**1.13**	**0.87**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**170**	**145**	**175**	**227**	**174**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.27**	**0.23**	**0.28**	**0.36**	**0.28**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	**0.94**	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	**589**	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	**44**	<1	<1	<1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	**1.33**	**0.03**	<0.01	**0.04**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**17300**	**14900**	**22700**	**31000**	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	----

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			*Client sample ID*	**NGS015-001K**	**NGS015-008K**	**NGS019-002K**	**NGS020-003K**	**NGS015-002**
			Client sampling date / time	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1310271-001**	**EB1310271-002**	**EB1310271-003**	**EB1310271-004**	**EB1310271-005**
EG005T: Total Metals by ICP-AES - Continued								
Iron	7439-89-6	50	mg/kg	**27900**	**21800**	**38800**	**63100**	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	**0.6**	**62.8**	**10.6**	**4.6**	----
Selenium	7782-49-2	1	mg/kg	<1	**5**	<1	<1	----
Silver	7440-22-4	0.1	mg/kg	<0.1	**0.1**	<0.1	<0.1	----
Barium	7440-39-3	0.1	mg/kg	**15.5**	**144**	**30.6**	**23.3**	----
Thallium	7440-28-0	0.1	mg/kg	<0.1	**0.1**	**0.2**	<0.1	----
Beryllium	7440-41-7	0.1	mg/kg	**1.1**	**1.7**	**1.2**	**0.6**	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----
Bismuth	7440-69-9	0.1	mg/kg	**0.1**	**6.2**	**0.4**	**0.2**	----
Cobalt	7440-48-4	0.1	mg/kg	**97.9**	**63.1**	**122**	**53.2**	----
Chromium	7440-47-3	0.1	mg/kg	**44.6**	**16.1**	**9.2**	**11.6**	----
Copper	7440-50-8	0.1	mg/kg	**4.3**	**5.8**	**28.8**	**205**	----
Thorium	7440-29-1	0.1	mg/kg	**6.1**	**12.6**	**8.6**	**7.3**	----
Manganese	7439-96-5	0.1	mg/kg	**104**	**85.8**	**164**	**347**	----
Strontium	7440-24-6	0.1	mg/kg	**7.4**	**3.2**	**3.8**	**3.7**	----
Molybdenum	7439-98-7	0.1	mg/kg	**1.4**	**23.2**	**2.3**	**4.3**	----
Nickel	7440-02-0	0.1	mg/kg	**32.2**	**222**	**19.1**	**27.6**	----
Lead	7439-92-1	0.1	mg/kg	**0.7**	**6.3**	**0.7**	**0.8**	----
Antimony	7440-36-0	0.1	mg/kg	<0.1	**0.2**	<0.1	<0.1	----
Uranium	7440-61-1	0.1	mg/kg	**1.2**	**8.3**	**2.1**	**1.9**	----
Zinc	7440-66-6	0.5	mg/kg	**33.2**	**9.6**	**45.5**	**62.4**	----
Lithium	7439-93-2	0.1	mg/kg	**15.6**	**2.2**	**16.8**	**11.9**	----
Vanadium	7440-62-2	1	mg/kg	**55**	**114**	**70**	**81**	----
Tin	7440-31-5	0.1	mg/kg	**2.2**	**0.9**	**2.9**	**2.5**	----

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			Client sample ID	**NGS015-003**	**NGS015-004**	**NGS015-007**	**NGS016-001**	**NGS016-002**
			Client sampling date / time	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00
Compound	CAS Number	LOR	Unit	**EB1310271-006**	**EB1310271-007**	**EB1310271-008**	**EB1310271-009**	**EB1310271-010**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H_2SO_4/t	**-24.1**	**-22.3**	**8.7**	**-9.0**	**-17.7**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**7.1**	**7.2**	**2.9**	**7.0**	**6.0**
NAG (pH 4.5)	----	0.1	kg H_2SO_4/t	<0.1	<0.1	**10.6**	<0.1	<0.1
NAG (pH 7.0)	----	0.1	kg H_2SO_4/t	<0.1	<0.1	**13.7**	<0.1	**0.2**
EA013: Acid Neutralising Capacity								
ANC as H_2SO_4	----	0.5	kg H_2SO_4 equiv./t	**25.6**	**22.3**	**6.9**	**9.0**	**20.5**
ANC as $CaCO_3$	----	0.1	% $CaCO_3$	**2.6**	**2.3**	**0.7**	**0.9**	**2.1**
Fizz Rating	----	0	Fizz Unit	**1**	**1**	**0**	**0**	**1**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**7.1**	**6.7**	**7.3**	**6.8**	**6.8**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.023**	**0.010**	**0.445**	<0.005	**0.091**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**14**	<10	**278**	<10	**57**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% $CaCO_3$	**1.57**	**1.32**	**0.72**	**0.84**	**1.25**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**315**	**264**	**145**	**167**	**250**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.50**	**0.42**	**0.23**	**0.27**	**0.40**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	**0.29**	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	**181**	<10	<10
Liming Rate	----	1	kg $CaCO_3$/t	<1	<1	**14**	<1	<1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.05**	<0.01	**0.51**	<0.01	**0.09**

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			*Client sample ID*	**NGS016-003**	**NGS016-004**	**NGS016-005**	**NGS016-007**	**NGS016-008**
			Client sampling date / time	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1310271-011**	**EB1310271-012**	**EB1310271-013**	**EB1310271-014**	**EB1310271-015**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-25.4**	**-8.2**	**-10.8**	**26.5**	**-11.1**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**7.1**	**6.5**	**3.4**	**2.8**	**7.4**
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	**2.8**	**24.8**	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	**0.2**	**6.5**	**32.2**	<0.1
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**25.4**	**10.0**	**25.2**	**5.6**	**17.2**
ANC as CaCO3	----	0.1	% CaCO3	**2.6**	**1.0**	**2.6**	**0.6**	**1.8**
Fizz Rating	----	0	Fizz Unit	**1**	**0**	**1**	**0**	**1**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**6.4**	**6.6**	**6.8**	**6.3**	**7.2**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	<0.005	**0.060**	**0.378**	**0.928**	**0.177**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**37**	**236**	**579**	**110**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	----	**1.40**	**1.60**	----	**2.44**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	----	**280**	**319**	----	**487**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	----	**0.45**	**0.51**	----	**0.78**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	**0.04**	**0.93**	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	**23**	**579**	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	**2**	**43**	<1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	**0.06**	**0.47**	**1.05**	**0.20**

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			*Client sample ID*	**NGS017-001**	**NGS017-002**	**NGS017-003**	**NGS017-004**	**NGS017-005**
			Client sampling date / time	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1310271-016**	**EB1310271-017**	**EB1310271-018**	**EB1310271-019**	**EB1310271-020**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-6.5**	**-1.7**	**-21.4**	**-22.2**	**-22.4**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**7.0**	**4.1**	**6.9**	**5.1**	**5.0**
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	**0.5**	<0.1	<0.1	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	**2.4**	<0.1	**1.1**	**1.0**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**6.5**	**8.4**	**22.6**	**28.6**	**30.7**
ANC as CaCO3	----	0.1	% CaCO3	**0.7**	**0.8**	**2.3**	**2.9**	**3.1**
Fizz Rating	----	0	Fizz Unit	**0**	**0**	**1**	**1**	**1**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**6.9**	**6.6**	**6.3**	**6.5**	**7.7**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	<0.005	**0.194**	**0.023**	**0.175**	**0.240**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**121**	**14**	**109**	**150**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**0.67**	**0.71**	----	**2.00**	**1.73**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**134**	**142**	----	**401**	**346**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.22**	**0.23**	----	**0.64**	**0.55**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	**0.04**	**0.02**	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	**26**	**14**	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	**2**	**1**	<1	<1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	**0.22**	**0.04**	**0.21**	**0.27**

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			*Client sample ID*	**NGS017-006**	**NGS017-007**	**NGS019-001**	**NGS019-003**	**NGS019-004**
			Client sampling date / time	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1310271-021**	**EB1310271-022**	**EB1310271-023**	**EB1310271-024**	**EB1310271-025**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-19.6**	**-25.6**	**-7.2**	**-7.4**	**-22.4**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**6.6**	**6.9**	**7.5**	**6.8**	**6.8**
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	<0.1	<0.1	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	<0.1	<0.1	<0.1	<0.1
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**21.7**	**27.8**	**7.2**	**8.9**	**23.9**
ANC as CaCO3	----	0.1	% CaCO3	**2.2**	**2.8**	**0.7**	**0.9**	**2.4**
Fizz Rating	----	0	Fizz Unit	**1**	**1**	**0**	**0**	**1**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**8.2**	**6.6**	**7.0**	**7.6**	**7.5**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.057**	**0.059**	**0.006**	**0.037**	**0.036**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**36**	**37**	<10	**23**	**22**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**1.40**	**1.97**	**0.65**	**0.95**	**1.62**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**279**	**394**	**130**	**189**	**323**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.45**	**0.63**	**0.21**	**0.30**	**0.52**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.07**	**0.07**	<0.01	**0.05**	**0.05**

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			*Client sample ID*	**NGS020-001**	**NGS020-002**	**NGS020-004**	**NGS020-005**	----
			Client sampling date / time	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	30-APR-2013 15:00	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1310271-026**	**EB1310271-027**	**EB1310271-028**	**EB1310271-029**	**----**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-2.1**	**-3.6**	**-9.2**	**-24.9**	----
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**7.1**	**7.2**	**7.2**	**7.6**	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	<0.1	<0.1	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	<0.1	<0.1	<0.1	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**2.1**	**3.6**	**10.1**	**24.9**	----
ANC as CaCO3	----	0.1	% CaCO3	**0.2**	**0.4**	**1.0**	**2.5**	----
Fizz Rating	----	0	Fizz Unit	**0**	**0**	**0**	**1**	----
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**5.5**	**6.9**	**7.2**	**7.2**	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	**6**	<2	<2	<2	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	<0.005	**0.005**	**0.020**	<0.005	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	**13**	<10	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	----	**0.48**	**1.35**	**1.87**	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	----	**96**	**269**	**374**	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	----	**0.15**	**0.43**	**0.60**	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	----
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	----
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	**0.03**	<0.01	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1314277**	Page	: 1 of 4
Client	: **EARTH SYSTEMS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR BRETT DAVIS	Contact	: Customer Services
Address	: SUITE 17 79-83 HIGH STREET KEW VIC, AUSTRALIA 3101	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: brett.davis@earthsystems.com.au	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 03 9810 7500	Telephone	: +61 7 3243 7222
Facsimile	: +61 03 9853 5030	Facsimile	: +61 7 3243 7218
Project	: NOWAN1202	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 12-JUN-2013
Sampler	: CHRIS HOSIE	Issue Date	: 24-JUN-2013
Site	: ----		
		No. of samples received	: 1
Quote number	: MEBQ/112/13	No. of samples analysed	: 1

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with
ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Dianne Blane	Laboratory Coordinator (2IC)	Newcastle - Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)			*Client sample ID*	**EB1310271020 (NGS017-005)**	----	----	----	----
			Client sampling date / time	30-APR-2013 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1314277-001**	**----**	**----**	**----**	**----**
EG005T: Total Metals by ICP-AES								
Boron	7440-42-8	50	mg/kg	<50	----	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	**6.3**	----	----	----	----
Cerium	7440-45-1	0.1	mg/kg	**28.8**	----	----	----	----
Germanium	7440-56-4	0.1	mg/kg	**0.6**	----	----	----	----
Selenium	7782-49-2	1	mg/kg	<1	----	----	----	----
Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
Barium	7440-39-3	0.1	mg/kg	**16.8**	----	----	----	----
Caesium	7440-46-2	0.1	mg/kg	**3.7**	----	----	----	----
Niobium	7440-03-1	0.1	mg/kg	<0.1	----	----	----	----
Thallium	7440-28-0	0.1	mg/kg	**0.4**	----	----	----	----
Beryllium	7440-41-7	0.1	mg/kg	**1.1**	----	----	----	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	----	----	----	----
Bismuth	7440-69-9	0.1	mg/kg	**0.3**	----	----	----	----
Cobalt	7440-48-4	0.1	mg/kg	**30.8**	----	----	----	----
Chromium	7440-47-3	0.1	mg/kg	**7.9**	----	----	----	----
Copper	7440-50-8	0.1	mg/kg	**30.3**	----	----	----	----
Thorium	7440-29-1	0.1	mg/kg	**4.6**	----	----	----	----
Gallium	7440-55-3	0.1	mg/kg	**19.6**	----	----	----	----
Strontium	7440-24-6	0.1	mg/kg	**2.6**	----	----	----	----
Tungsten	7440-33-7	0.1	mg/kg	**0.4**	----	----	----	----
Hafnium	7440-58-6	1	mg/kg	<1	----	----	----	----
Molybdenum	7439-98-7	0.1	mg/kg	**2.6**	----	----	----	----
Nickel	7440-02-0	0.1	mg/kg	**5.5**	----	----	----	----
Indium	7440-74-6	0.1	mg/kg	**0.1**	----	----	----	----
Lead	7439-92-1	0.1	mg/kg	**0.6**	----	----	----	----
Antimony	7440-36-0	0.1	mg/kg	<0.1	----	----	----	----
Lanthanum	7439-91-0	0.1	mg/kg	**13.3**	----	----	----	----
Uranium	7440-61-1	0.1	mg/kg	**1.2**	----	----	----	----
Zinc	7440-66-6	0.5	mg/kg	**48.2**	----	----	----	----
Lithium	7439-93-2	0.1	mg/kg	**16.4**	----	----	----	----
Rubidium	7440-17-7	0.1	mg/kg	**156**	----	----	----	----
Vanadium	7440-62-2	1	mg/kg	**87**	----	----	----	----

Analytical Results

Sub-Matrix: **PULP** (Matrix: **SOIL**)			Client sample ID	**EB1310271020 (NGS017-005)**	----	----	----	----
			Client sampling date / time	30-APR-2013 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	**EB1314277-001**	**----**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS - Continued								
Tin	7440-31-5	0.1	mg/kg	**1.8**	----	----	----	----
Tellurium	22541-49-7	0.5	mg/kg	<0.5	----	----	----	----
Yttrium	7440-65-5	0.1	mg/kg	**9.4**	----	----	----	----
Zirconium	7440-67-7	0.5	mg/kg	**23.7**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	----	----	----
EK040T: Fluoride Total								
Fluoride	16984-48-8	40	mg/kg	**2920**	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	**EM1305501**	Page	1 of 5
Amendment	**1**		
Client	**EARTH SYSTEMS PTY LTD**	Laboratory	Environmental Division Melbourne
Contact	MR BRETT DAVIS	Contact	Client Services
Address	SUITE 17 79-83 HIGH STREET KEW VIC, AUSTRALIA 3101	Address	4 Westall Rd Springvale VIC Australia 3171
E-mail	brett.davis@earthsystems.com.au	E-mail	Melbourne.Enviro.Services@alsglobal.com
Telephone	+61 03 9810 7500	Telephone	+61-3-8549 9600
Facsimile	+61 03 9853 5030	Facsimile	+61-3-8549 9601
Project	NOWAN1202	QC Level	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	----		
C-O-C number	----	Date Samples Received	24-MAY-2013
Sampler	BD	Issue Date	06-JUN-2013
Site	Nowa Nowa		
		No. of samples received	1
Quote number	MEBQ/112/12	No. of samples analysed	1

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics
SATISH.TRIVEDI	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils
Stephen Hislop	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics

General Comments

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LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **All analysis except for Total Fluoride conducted by ALS Brisbane, NATA Site No. 818.**
- **ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.**
- **ASS: EA033 (CRS Suite): SKCl and SHCl to be analysed and reported regardless of pHKCl value**
- **This report has been amended to report total carbon. 6/6/13 PR**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**LIMS Tails**	----	----	----	----
			Client sampling date / time	23-MAY-2013 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1305501-001**	**----**	**----**	**----**	**----**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**2.3**	----	----	----	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	**82.4**	----	----	----	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	**90.6**	----	----	----	----
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**7.5**	----	----	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	----	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**5.63**	----	----	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**3510**	----	----	----	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**1.17**	----	----	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**234**	----	----	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.38**	----	----	----	----
EA033-D: Retained Acidity								
KCl Extractable Sulfur (23Ce)	----	0.02	% S	**0.03**	----	----	----	----
HCl Extractable Sulfur (20Be)	----	0.02	% S	**0.03**	----	----	----	----
Net Acid Soluble Sulfur (20Je)	----	0.02	% S	<0.02	----	----	----	----
acidity - Net Acid Soluble Sulfur (a-20J)	----	10	mole H+ / t	<10	----	----	----	----
sulfidic - Net Acid Soluble Sulfur (s-20J)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	----	----	----	----
Net Acidity (sulfur units)	----	0.02	% S	**5.38**	----	----	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	**3350**	----	----	----	----
Liming Rate	----	1	kg CaCO3/t	**252**	----	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**3.9**	----	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**7.32**	----	----	----	----
EG005T: Total Metals by ICP-AES								
Boron	7440-42-8	50	mg/kg	**60**	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			*Client sample ID*	**LIMS Tails**	----	----	----	----
			Client sampling date / time	23-MAY-2013 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1305501-001**	**----**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	**31.9**	----	----	----	----
Cerium	7440-45-1	0.1	mg/kg	**17.6**	----	----	----	----
Germanium	7440-56-4	0.1	mg/kg	**1.5**	----	----	----	----
Selenium	7782-49-2	1	mg/kg	**3**	----	----	----	----
Silver	7440-22-4	0.1	mg/kg	**0.6**	----	----	----	----
Barium	7440-39-3	0.1	mg/kg	**10.8**	----	----	----	----
Caesium	7440-46-2	0.1	mg/kg	**1.8**	----	----	----	----
Niobium	7440-03-1	0.1	mg/kg	<0.1	----	----	----	----
Thallium	7440-28-0	0.1	mg/kg	**0.2**	----	----	----	----
Beryllium	7440-41-7	0.1	mg/kg	**2.3**	----	----	----	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	----	----	----	----
Bismuth	7440-69-9	0.1	mg/kg	**6.4**	----	----	----	----
Cobalt	7440-48-4	0.1	mg/kg	**420**	----	----	----	----
Chromium	7440-47-3	0.1	mg/kg	**12.2**	----	----	----	----
Copper	7440-50-8	0.1	mg/kg	**4140**	----	----	----	----
Thorium	7440-29-1	0.1	mg/kg	**2.9**	----	----	----	----
Gallium	7440-55-3	0.1	mg/kg	**12.0**	----	----	----	----
Strontium	7440-24-6	0.1	mg/kg	**2.2**	----	----	----	----
Tungsten	7440-33-7	0.1	mg/kg	**3.7**	----	----	----	----
Hafnium	7440-58-6	1	mg/kg	<1	----	----	----	----
Molybdenum	7439-98-7	0.1	mg/kg	**9.2**	----	----	----	----
Nickel	7440-02-0	0.1	mg/kg	**13.3**	----	----	----	----
Indium	7440-74-6	0.1	mg/kg	**2.5**	----	----	----	----
Lead	7439-92-1	0.1	mg/kg	**1.3**	----	----	----	----
Antimony	7440-36-0	0.1	mg/kg	**0.2**	----	----	----	----
Lanthanum	7439-91-0	0.1	mg/kg	**8.5**	----	----	----	----
Uranium	7440-61-1	0.1	mg/kg	**1.4**	----	----	----	----
Zinc	7440-66-6	0.5	mg/kg	**28.8**	----	----	----	----
Lithium	7439-93-2	0.1	mg/kg	**6.5**	----	----	----	----
Rubidium	7440-17-7	0.1	mg/kg	**63.8**	----	----	----	----
Vanadium	7440-62-2	1	mg/kg	**17**	----	----	----	----
Tin	7440-31-5	0.1	mg/kg	**1.5**	----	----	----	----
Tellurium	22541-49-7	0.5	mg/kg	**0.8**	----	----	----	----
Yttrium	7440-65-5	0.1	mg/kg	**14.4**	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**

			Client sample ID	**LIMS Tails**	----	----	----	----
			Client sampling date / time	23-MAY-2013 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1305501-001**	**----**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS - Continued								
Zirconium	7440-67-7	0.5	mg/kg	**8.2**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	**0.1**	----	----	----	----
EK040T: Fluoride Total								
Fluoride	16984-48-8	40	mg/kg	**1670**	----	----	----	----
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.06**	----	----	----	----
EP003TC: Total Carbon (TC) in Soil								
Total Carbon	----	0.02	%	**0.16**	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EM1306857**	Page	: 1 of 4
Client	: **EARTH SYSTEMS PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MR BRETT DAVIS	Contact	: Client Services
Address	: SUITE 17 79-83 HIGH STREET KEW VIC, AUSTRALIA 3101	Address	: 4 Westall Rd Springvale VIC Australia 3171
E-mail	: brett.davis@earthsystems.com.au	E-mail	: Melbourne.Enviro.Services@alsglobal.com
Telephone	: +61 03 9810 7500	Telephone	: +61-3-8549 9600
Facsimile	: +61 03 9853 5030	Facsimile	: +61-3-8549 9601
Project	: NOWAN1202	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 27-JUN-2013
Sampler	: BD	Issue Date	: 03-JUL-2013
Site	: ----		
		No. of samples received	: 3
Quote number	: MEBQ/112/13	No. of samples analysed	: 3

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with
ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics
Varsha Ho Wing	Non-Metals Team Leader	Melbourne Inorganics
Varsha Ho Wing	Non-Metals Team Leader	Melbourne Inorganics
Varsha Ho Wing	Non-Metals Team Leader	Melbourne Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EA010 : EM1306857-003 for conductivity has been confirmed by re-analysis.**
- **EG035F:EM1306828#2 matrix spike failed for mercury due to possible sample matrix interference. This has been confirmed by repreparation and re-analysis.**
- **EK040P : EM1306836-008 matrix spike failed for Fluoride. This has been confirmed by re-analysis.**
- **Ionic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium.**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**NGS017-005**	**NGS015-008K**	**LIMS Tails**	----	----
			Client sampling date / time	25-JUN-2013 15:00	25-JUN-2013 15:00	19-JUN-2013 15:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1306857-001**	**EM1306857-002**	**EM1306857-003**	**----**	**----**
EA005: pH								
pH Value	----	0.01	pH Unit	**6.81**	**5.53**	**5.43**	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	**71**	**477**	**4900**	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**4**	<1	<1	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**4**	<1	<1	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**3**	**5**	**103**	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**14**	**46**	**3430**	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**8**	**117**	**171**	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	**7**	**432**	----	----
Magnesium	7439-95-4	1	mg/L	**1**	**14**	**492**	----	----
Sodium	7440-23-5	1	mg/L	**10**	**57**	**177**	----	----
Potassium	7440-09-7	1	mg/L	**2**	**3**	**47**	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.08**	**0.14**	**0.06**	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	**0.001**	**0.001**	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	**0.0037**	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Copper	7440-50-8	0.001	mg/L	**0.003**	**0.006**	**38.3**	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	**0.054**	**2.51**	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	**0.298**	**0.222**	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	**0.003**	<0.001	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	**0.029**	**1.56**	----	----
Manganese	7439-96-5	0.001	mg/L	**0.005**	**0.066**	**20.1**	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	**0.002**	<0.001	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**NGS017-005**	**NGS015-008K**	**LIMS Tails**	----	----
			Client sampling date / time	25-JUN-2013 15:00	25-JUN-2013 15:00	19-JUN-2013 15:00	----	----
Compound	CAS Number	LOR	Unit	**EM1306857-001**	**EM1306857-002**	**EM1306857-003**	**----**	**----**
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	<0.01	**0.01**	<0.01	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Tellurium	22541-49-7	0.005	mg/L	<0.005	<0.005	<0.005	----	----
Thallium	7440-28-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Tin	7440-31-5	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	**0.006**	**0.001**	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Boron	7440-42-8	0.05	mg/L	**0.22**	**0.13**	**0.15**	----	----
Iron	7439-89-6	0.05	mg/L	**0.09**	**0.31**	<0.05	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.9**	**0.2**	**0.4**	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.01	<0.01	<0.01	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**0.60**	**4.26**	**76.2**	----	----
Total Cations	----	0.01	meq/L	**0.57**	**4.06**	**71.0**	----	----
Ionic Balance	----	0.01	%	**2.48**	**2.42**	**3.59**	----	----

Acid Buffering Characteristic Curve (ABCC) REPORT

Batch: EB1317068

CONTACT:	BRETT DAVIS	**LABORATORY:**	Brisbane
CLIENT:	EARTH SYSTEMS PTY LTD	**DATE SAMPLED:**	Various
ADDRESS:	SUITE 17 79-83 HIGH STREET KEW, VIC, AUSTRALIA 310	**DATE RECEIVED:**	17/07/2013
		DATE COMPLETED:	23/07/2013
		SAMPLE TYPE:	Soil
		No. of SAMPLES:	3

COMMENTS

EA046 : NATA accreditation does not cover performance of this service.

ISSUING LABORATORY: ALS BRISBANE

Address:	32 Shand Street STAFFORD QLD 4053 AUSTRALIA	**Telephone:**	07 3243 7222
		Facsimile:	07 3243 7218
		E-mail:	Satishkumar.Trivedi@alsglobal.com

Signatory

Australian Laboratory Services Pty Ltd (ABN 84 009 936 029)

Work Order :	EB1317068	Client ID:	EARTH SYSTEMS PTY LTD

	Sub Matrix			Soil
	Client Sample Identification 1			LIMS Tails
	Client Sample Identification 2			
	Sample Date			Various
Method	Analyte	Units	LOR	
				1 EB1317068

EA046 - A Titration information

HCl Molarity:	**M**	**0.1**
Increments:	**mL**	**0.2**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**10.1**

EA046 -B - Curve information

Addition	mLs added (total)	kg H2SO4/t	pH	Addition	mLs added (total)	kg H2SO4/t	pH
0	0	0	7.65	36	7.2	17.64	2.54
1	0.2	0.49	5.83	37	7.4	18.13	2.53
2	0.4	0.98	5.11	38	7.6	18.62	2.51
3	0.6	1.47	4.78	39	7.8	19.11	2.50
4	0.8	1.96	4.50	40	8	19.6	2.48
5	1	2.45	4.25	41	8.2	20.09	2.47
6	1.2	2.94	4.04				
7	1.4	3.43	3.86				
8	1.6	3.92	3.71				
9	1.8	4.41	3.59				
10	2	4.9	3.49				
11	2.2	5.39	3.40				
12	2.4	5.88	3.33				
13	2.6	6.37	3.26				
14	2.8	6.86	3.20				
15	3	7.35	3.14				
16	3.2	7.84	3.09				
17	3.4	8.33	3.04				
18	3.6	8.82	3.00				
19	3.8	9.31	2.96				
20	4	9.8	2.92				
21	4.2	10.29	2.88				
22	4.4	10.78	2.85				
23	4.6	11.27	2.82				
24	4.8	11.76	2.79				
25	5	12.25	2.76				
26	5.2	12.74	2.73				
27	5.4	13.23	2.71				
28	5.6	13.72	2.69				
29	5.8	14.21	2.67				
30	6	14.7	2.65				
31	6.2	15.19	2.63				
32	6.4	15.68	2.61				
33	6.6	16.17	2.59				
34	6.8	16.66	2.57				
35	7	17.15	2.56				

Work Order :	**EB1317068**	**Client ID:**	**EARTH SYSTEMS PTY LTD**

	Sub Matrix			Soil
	Client Sample Identification 1			LIMS Tails
	Client Sample Identification 2			
	Sample Date			Various
Method	Analyte	Units	LOR	
				1 **Check** **EB1317068**

EA046 - A Titration information

HCl Molarity:	**M**	**0.1**
Increments:	**mL**	**0.2**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**10.1**

EA046 -B - Curve information

Addition	**mLs added (total)**	**kg H2SO4/t**	**pH**	**Addition**	**mLs added (total)**	**kg H2SO4/t**	**pH**
0	0	0	7.69	36	7.2	17.64	2.51
1	0.2	0.49	5.80	37	7.4	18.13	2.50
2	0.4	0.98	5.09	38	7.6	18.62	2.50
3	0.6	1.47	4.76	39	7.8	19.11	2.49
4	0.8	1.96	4.47	40	8	19.6	2.48
5	1	2.45	4.24				
6	1.2	2.94	4.00				
7	1.4	3.43	3.84				
8	1.6	3.92	3.70				
9	1.8	4.41	3.59				
10	2	4.9	3.48				
11	2.2	5.39	3.39				
12	2.4	5.88	3.30				
13	2.6	6.37	3.24				
14	2.8	6.86	3.18				
15	3	7.35	3.12				
16	3.2	7.84	3.08				
17	3.4	8.33	3.03				
18	3.6	8.82	2.99				
19	3.8	9.31	2.95				
20	4	9.8	2.90				
21	4.2	10.29	2.88				
22	4.4	10.78	2.83				
23	4.6	11.27	2.80				
24	4.8	11.76	2.78				
25	5	12.25	2.76				
26	5.2	12.74	2.72				
27	5.4	13.23	2.70				
28	5.6	13.72	2.68				
29	5.8	14.21	2.66				
30	6	14.7	2.62				
31	6.2	15.19	2.60				
32	6.4	15.68	2.59				
33	6.6	16.17	2.57				
34	6.8	16.66	2.56				
35	7	17.15	2.54				

Work Order : **EB1317068** **Client ID:** **EARTH SYSTEMS PTY LTD**

	Sub Matrix			Soil
	Client Sample Identification 1			NGS017-005
	Client Sample Identification 2			
	Sample Date			Various
Method	Analyte	Units	LOR	
				2 **EB1317068**

EA046 - A Titration information

HCl Molarity:	**M**	**0.1**
Increments:	**mL**	**0.5**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**30.7**

EA046 -B - Curve information

Addition	**mLs added (total)**	**kg H2SO4/t**	**pH**	**Addition**	**mLs added (total)**	**kg H2SO4/t**	**pH**
0	0	0	8.03				
1	0.5	1.225	5.81				
2	1	2.45	5.14				
3	1.5	3.675	4.81				
4	2	4.9	4.53				
5	2.5	6.125	4.25				
6	3	7.35	3.95				
7	3.5	8.575	3.70				
8	4	9.8	3.50				
9	4.5	11.025	3.35				
10	5	12.25	3.23				
11	5.5	13.475	3.13				
12	6	14.7	3.05				
13	6.5	15.925	2.98				
14	7	17.15	2.93				
15	7.5	18.375	2.88				
16	8	19.6	2.84				
17	8.5	20.825	2.80				
18	9	22.05	2.76				
19	9.5	23.275	2.73				
20	10	24.5	2.70				
21	10.5	25.725	2.67				
22	11	26.95	2.64				
23	11.5	28.175	2.62				
24	12	29.4	2.59				
25	12.5	30.625	2.57				
26	13	31.85	2.55				
27	13.5	33.075	2.53				
28	14	34.3	2.51				
29	14.5	35.525	2.49				
30	15	36.75	2.47				
31	15.5	37.975	2.45				

Work Order :	**EB1317068**	**Client ID:**	**EARTH SYSTEMS PTY LTD**	

	Sub Matrix			Soil
	Client Sample Identification 1			NGS015-008K
	Client Sample Identification 2			
	Sample Date			Various
Method	Analyte	Units	LOR	
				3 **EB1317068**

EA046 - A Titration information

HCl Molarity:	**M**	**0.1**
Increments:	**mL**	**0.1**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**7.4**

EA046 -B - Curve information

Addition	**mLs added (total)**	**kg H2SO4/t**	**pH**	**Addition**	**mLs added (total)**	**kg H2SO4/t**	**pH**
0	0	0	6.92	36	3.6	8.82	3.04
1	0.1	0.245	5.52	37	3.7	9.065	3.02
2	0.2	0.49	4.91	38	3.8	9.31	3.00
3	0.3	0.735	4.63	39	3.9	9.555	2.98
4	0.4	0.98	4.47	40	4	9.8	2.96
5	0.5	1.225	4.35	41	4.1	10.045	2.94
6	0.6	1.47	4.24	42	4.2	10.29	2.92
7	0.7	1.715	4.14	43	4.3	10.535	2.91
8	0.8	1.96	4.06	44	4.4	10.78	2.89
9	0.9	2.205	3.98	45	4.5	11.025	2.88
10	1	2.45	3.92	46	4.6	11.27	2.86
11	1.1	2.695	3.85	47	4.7	11.515	2.85
12	1.2	2.94	3.79	48	4.8	11.76	2.83
13	1.3	3.185	3.73	49	4.9	12.005	2.82
14	1.4	3.43	3.69	50	5	12.25	2.80
15	1.5	3.675	3.64	51	5.1	12.495	2.79
16	1.6	3.92	3.60	52	5.2	12.74	2.78
17	1.7	4.165	3.55	53	5.3	12.985	2.76
18	1.8	4.41	3.52	54	5.4	13.23	2.75
19	1.9	4.655	3.48	55	5.5	13.475	2.74
20	2	4.9	3.44	56	5.6	13.72	2.73
21	2.1	5.145	3.41	57	5.7	13.965	2.72
22	2.2	5.39	3.41	58	5.8	14.21	2.71
23	2.3	5.635	3.41	59	5.9	14.455	2.70
24	2.4	5.88	3.37	60	6	14.7	2.69
25	2.5	6.125	3.34	61	6.1	14.945	2.68
26	2.6	6.37	3.30	62	6.2	15.19	2.67
27	2.7	6.615	3.27	63	6.3	15.435	2.66
28	2.8	6.86	3.24	64	6.4	15.68	2.66
29	2.9	7.105	3.21	65	6.5	15.925	2.65
30	3	7.35	3.18	66	6.6	16.17	2.64
31	3.1	7.595	3.15	67	6.7	16.415	2.63
32	3.2	7.84	3.13	68	6.8	16.66	2.63
33	3.3	8.085	3.11	69	6.9	16.905	2.62
34	3.4	8.33	3.08	70	7	17.15	2.61
35	3.5	8.575	3.06	71	7.1	17.395	2.61

Work Order :	**EB1317068**	**Client ID:**	**EARTH SYSTEMS PTY LTD**

	Sub Matrix			Soil
	Client Sample Identification 1			NGS015-008K
	Client Sample Identification 2			
	Sample Date			Various
Method	Analyte	Units	LOR	
				3 **EB1317068**

EA046 - A Titration information

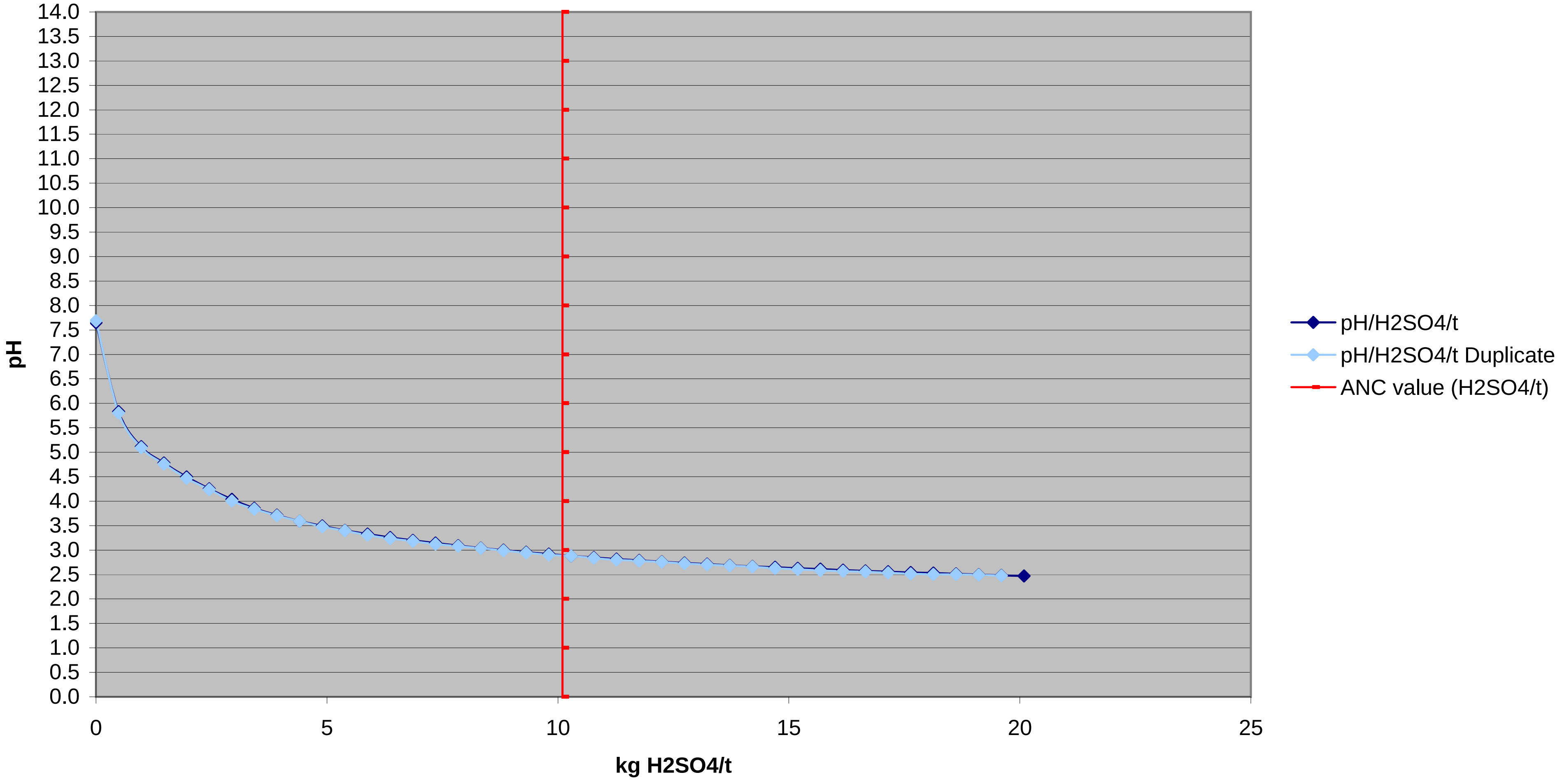
HCl Molarity:	**M**	**0.1**
Increments:	**mL**	**0.1**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**7.4**

EA046 -B - Curve information

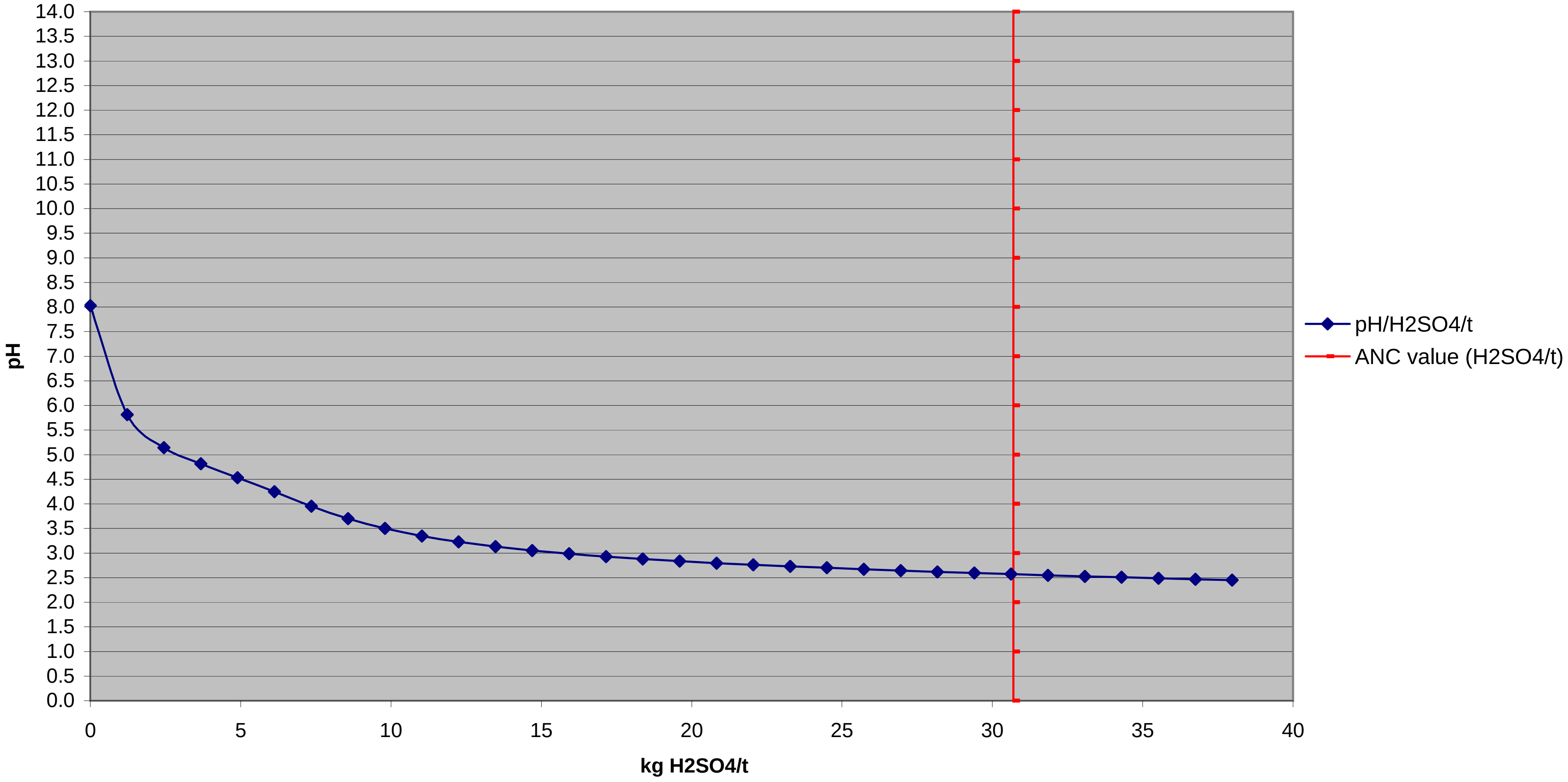
Addition	**mLs added (total)**	**kg H2SO4/t**	**pH**	**Addition**	**mLs added (total)**	**kg H2SO4/t**	**pH**
72	7.2	17.64	2.60				
73	7.3	17.885	2.59				
74	7.4	18.13	2.58				
75	7.5	18.375	2.57				
76	7.6	18.62	2.57				
77	7.7	18.865	2.56				
78	7.8	19.11	2.55				
79	7.9	19.355	2.54				
80	8	19.6	2.54				
81	8.1	19.845	2.53				
82	8.2	20.09	2.52				
83	8.3	20.335	2.52				
84	8.4	20.58	2.53				
85	8.5	20.825	2.53				
86	8.6	21.07	2.53				
87	8.7	21.315	2.52				
88	8.8	21.56	2.52				
89	8.9	21.805	2.51				
90	9	22.05	2.50				
91	9.1	22.295	2.50				
92	9.2	22.54	2.49				
93	9.3	22.785	2.48				

EB1317068 - 001 & 001 Ck (LIMS Tails)
Acid Buffering Characteristic Curve

Titrating with 0.1M HCl, in increments of 0.2 mLs every 1000 seconds



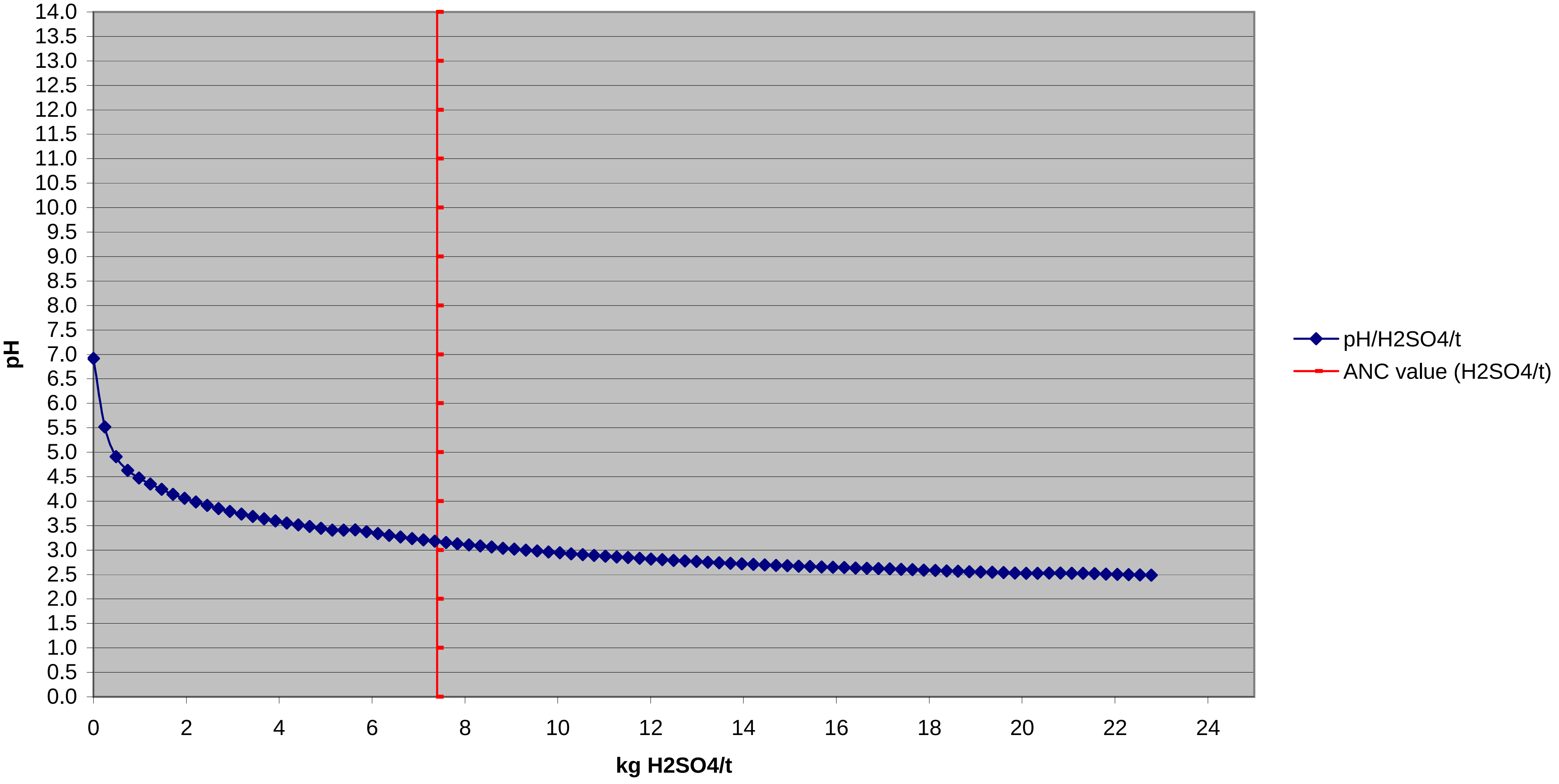
EB1317068 - 002 (NGS017-005)
Acid Buffering Characteristic Curve
Titrating with 0.1M HCl, in increments of 0.5 mLs every 1000 seconds



EB1317068 - 003 (NGS015-008K)

Acid Buffering Characteristic Curve

Titrating with 0.1M HCl, in increments of 0.1 mLs every 1000 seconds



ALS
minerals

Australian Laboratory Services Pty. Ltd.
32 Shand Street
Stafford
Brisbane QLD 4053
Phone: +61 (7) 3243 7222 Fax: +61 (7) 3243 7218
www.alsglobal.com

Finalized Date: 20-JUN-2013
Account: ALSENV

CERTIFICATE BR13107633

Project: EB1314277
P.O. No.:
This report is for 1 Pulp sample submitted to our lab in Brisbane, QLD, Australia on 14-JUN-2013.
The following have access to data associated with this certificate:

SUB RESULTS

SAMPLE PREPARATION

ALS CODE	DESCRIPTION
LOG-22	Sample login – Rcd w/o BarCode

ANALYTICAL PROCEDURES

ALS CODE	DESCRIPTION	INSTRUMENT
ME-XRF21n	Iron Ore by XRF Fusion	XRF
ME-GRA05	H2O/LOI by TGA furnace	TGA

To: **ALS ENVIRONMENTAL**
ATTN: SUB RESULTS
32 SHAND STREET
STAFFORD QLD 4053

This is the Final Report and supersedes any preliminary report with this certificate number. Results apply to samples as submitted. All pages of this report have been checked and approved for release.

***** See Appendix Page for comments regarding this certificate *****

Signature:

Shaun Kenny, Brisbane Laboratory Manager

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Project: EB1314277

CERTIFICATE OF ANALYSIS BR13107633

Sample Description	Method Analyte Units LOR	ME-GRA05 LOI % 0.01	ME-XRF21n Al % 0.005	ME-XRF21n Ca % 0.007	ME-XRF21n Cl % 0.001	ME-XRF21n Fe % 0.01	ME-XRF21n Mg % 0.006	ME-XRF21n Mn % 0.001	ME-XRF21n P % 0.001	ME-XRF21n K % 0.0006	ME-XRF21n Na % 0.004	ME-XRF21n S % 0.001	ME-XRF21n Ti % 0.006
EB1310271020 (NGS012-005)		2.75	8.76	0.194	0.035	8.51	4.56	0.039	0.044	1.360	4.31	0.296	0.484

***** See Appendix Page for comments regarding this certificate *****

CERTIFICATE OF ANALYSIS BR13107633

	CERTIFICATE COMMENTS
Applies to Method:	

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Page: 1
Finalized Date: 20-JUN-2013
Account: ALSENV

QC CERTIFICATE BR13107633

Project: EB1314277
P.O. No.:
This report is for 1 Pulp sample submitted to our lab in Brisbane, QLD, Australia on 14-JUN-2013.
The following have access to data associated with this certificate:

SUB RESULTS		

SAMPLE PREPARATION

ALS CODE	DESCRIPTION
LOG-22	Sample login - Rcd w/o BarCode

ANALYTICAL PROCEDURES

ALS CODE	DESCRIPTION	INSTRUMENT
ME-XRF21n	Iron Ore by XRF Fusion	XRF
ME-GRA05	H2O/LOI by TGA furnace	TGA

To: ALS ENVIRONMENTAL
ATTN: SUB RESULTS
32 SHAND STREET
STAFFORD QLD 4053

This is the Final Report and supersedes any preliminary report with this certificate number. Results apply to samples as submitted. All pages of this report have been checked and approved for release.

***** See Appendix Page for comments regarding this certificate *****

Signature:

Shaun Kenny, Brisbane Laboratory Manager

QC CERTIFICATE OF ANALYSIS BR13107633

Sample Description	Method Analyte Units LOR	ME-GRA05 LOI % 0.01	ME-XRF21n Al % 0.005	ME-XRF21n Ca % 0.007	ME-XRF21n Cl % 0.001	ME-XRF21n Fe % 0.01	ME-XRF21n Mg % 0.006	ME-XRF21n Mn % 0.001	ME-XRF21n P % 0.001	ME-XRF21n K % 0.0008	ME-XRF21n Na % 0.004	ME-XRF21n S % 0.001	ME-XRF21n Ti % 0.006
						STANDARDS							
LAT-C59		12.56											
LAT-C59		12.53											
Target Range - Lower Bound		12.34											
Upper Bound		13.12											
NCS 14012a			1.735	5.56	0.026	37.81	2.18	0.140	0.079	0.618	0.404	0.599	0.096
Target Range - Lower Bound			1.700	5.34	0.021	37.40	2.13	0.141	0.073	0.567	0.367	0.575	0.091
Upper Bound			1.780	5.57	0.027	38.18	2.23	0.158	0.083	0.628	0.445	0.632	0.115
NCSDC73303			7.32	6.29	0.012	9.42	4.62	0.125	0.430	1.910	2.48	0.010	1.425
Target Range - Lower Bound			7.17	6.16	0.009	9.27	4.59	0.123	0.391	1.830	2.25	<0.001	1.345
Upper Bound			7.47	6.43	0.015	9.48	4.79	0.139	0.435	2.02	2.76	0.002	1.495
SARM-12			0.420	0.810	0.012	66.52	1.735	0.173	0.047	0.0082	0.010	0.070	0.446
Target Range - Lower Bound			0.397	0.756	0.008	65.98	1.650	0.160	0.044	0.0092	<0.004	0.065	0.404
Upper Bound			0.423	0.802	0.014	67.33	1.730	0.179	0.051	0.0124	0.018	0.074	0.455
						BLANKS							
BLANK			<0.005	<0.007	<0.001	0.01	<0.006	<0.001	0.001	0.0017	<0.004	<0.001	<0.006
Target Range - Lower Bound			<0.005	<0.007	<0.001	<0.01	<0.006	<0.001	<0.001	<0.0008	<0.004	<0.001	<0.006
Upper Bound			0.010	0.014	0.002	0.02	0.012	0.002	0.002	0.0016	0.008	0.002	0.012
						DUPLICATES							
PTL					0.058	12.08		0.158	0.032			1.635	
DUP			2.52	11.70	0.059	12.10	6.95	0.158	0.032	0.290	1.290	1.640	0.180
Target Range - Lower Bound			2.49	11.60	0.055	12.02	6.87	0.153	0.030	0.282	1.220	1.595	0.170
Upper Bound			2.55	11.80	0.062	12.16	7.03	0.163	0.034	0.298	1.360	1.680	0.191
EB1310271020 (NG5017-005)		2.75	8.76	0.194	0.035	8.51	4.56	0.039	0.084	1.360	4.31	0.296	0.484
DUP		4.32	8.73	0.202	0.035	8.51	4.57	0.038	0.085	1.355	4.34	0.298	0.487
Target Range - Lower Bound		3.44	8.65	0.189	0.032	8.46	4.51	0.037	0.081	1.325	4.10	0.289	0.467
Upper Bound		3.63	8.84	0.207	0.038	8.58	4.62	0.040	0.088	1.390	4.55	0.305	0.504

QC CERTIFICATE OF ANALYSIS BR13107633

Sample Description	Method Analyte Units LOR	ME-GRA05 LOI % 0.01	ME-XRF21n Al % 0.005	ME-XRF21n Ca % 0.007	ME-XRF21n Cl % 0.001	ME-XRF21n Fe % 0.01	ME-XRF21n Mg % 0.006	ME-XRF21n Mn % 0.001	ME-XRF21n P % 0.001	ME-XRF21n K % 0.0008	ME-XRF21n Na % 0.004	ME-XRF21n S % 0.001	ME-XRF21n Ti % 0.006
		DUPLICATES											
ORIGINAL		2.61											
DUP		2.68											
Target Range - Lower Bound		2.58											
Upper Bound		2.71											

QC CERTIFICATE OF ANALYSIS BR13107633

	CERTIFICATE COMMENTS
Applies to Method:	