EcOz Environmental Services

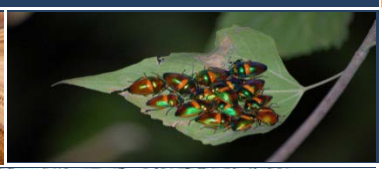
Appendix G Assessment of potential for Acid Mine Drainage (AMD)

Sherwin Iron (NT) Pty Ltd

Sherwin Creek Iron Ore Project

Environmental Impact Statement





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Acid Mine/Metalliferous Drainage (AMD)

Implications for Mine Waste Management

Deposit C Sherwin Creek Iron Ore Project

Sherwin Iron Ltd

Revision No 2
November 2013

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Report

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Note: Raw data has been excluded from the Appendices. The data can be obtained by contacting ecoz@ecoz.com.au requesting 'Sherwin Iron AMD Data' or by calling (08) 8981 1100 and requesting the same.

Abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASLP	Australian Standard Leaching Procedures
DEHWA	Commonwealth Department of the Environment, Water, Heritage and the Arts
DME	Northern Territory Department of Mines and Energy
LoR	Limit of Reporting
MMP	Mining Management Plan
NLC	Northern Land Council
WMP	Water Management Plan
ha	hectare
hr	hour
km	kilometre
m	metre
yr	year
s	second

Acid Mine Drainage:

Acronym	Parameter Definition/(Determination)	Unit
ACM	Acid Consuming Materials	kgH_2SO_4/ton
AFP	Acid Formation Potential	kgH_2SO_4/ton
AMD	Acid Metalliferous Drainage The generic term Acid Mine Drainage is used to describe the low pH subset of mine drainage; however, not all drainage as a result of the oxidation of sulfides is acidic. The term Acid Metalliferous Drainage is used to describe the capacity to release metals on exposure to acidic waters although not all sulfide minerals are acid producing during oxidation.	
ANC	Acid Neutralisation Capacity (Laboratory Analysis)	kgH_2SO_4/ton
APR	Acid Potential Ratios (Calculation)	
ARD	Acid Rock Drainage The generic term is used to describe the low pH subset of oxidised naturally occurring sulfide bearing materials.	
MPA	Maximum-Potential Acidity (Calculation)	kgH_2SO_4/ton
NAF	Non Acid Forming (Calculation): - Sulfide-S < 0.3% - Sulfide-S ≥ 0.3%, and negative NAPP value with ANC/MPA ≥ 2.0	kgH_2SO_4/ton
NAG	Net Acid Generation (Laboratory Analysis)	kgH_2SO_4/ton
NAPP	Net Acid Producing Potential (Calculation)	kgH_2SO_4/ton
PAF	Potential Acid Forming (Calculation): - Sulfide-S ≥ 0.3% and any positive NAPP value - Sulfide-S ≥ 0.3% and a negative NAPP value with ANC/MPA < 2.0	kgH_2SO_4/ton
SOR	Sulfide Oxidation Rate ['kinetic' testing]	$mgSO_4/kg/week$
Sulfide-S	Sulfide Sulfur [Sulfide-S = Total-S - Sulfate-S]	%(w/w)
Total-S	Total Sulfur (Laboratory Analysis)	%(w/w)

Executive Summary

Pendragon Environmental Solutions Pty Ltd was engaged by EcOz Environmental Services, on behalf of Sherwin Iron Ltd, to undertake an acid mine/metalliferous drainage (AMD) assessment of Deposit C, Sherwin Creek Iron Ore Project, to ascertain the potential for AMD generation and to characterise the potential availability and enrichment of metals and thus the potential impacts to the surrounding environment and water resources.

This document details the geological and geochemical characterization of overburden, waste rock and ore samples, a preliminary conceptual site model, evaluates the acid producing potential (APP) and includes recommendations for management plans during mining.

The scope of works included:

- Characterise selected exploration drill-core rock samples in terms of their APP properties.
- Characterise selected number of samples from the bulk sampling area in terms of their APP.
- Develop a conceptual site model indicating risks, opportunities, constraints and potential outcomes.
- Analyse the APP of overburden, waste rock and ore materials and to assess the potential for enrichment and/or release of available metals to the environment.
- Assess the likely potential impacts and risks on surface and ground water and the surrounding environment.
- Evaluate results and assess the implications for mining with regard to waste rock management.

The assessment of the potential for AMD potential of the overburden, waste rock and ore materials at Deposit C followed a two way investigation approach:

- Develop a conceptual model based upon a mineralogical assessment of about 2,541 samples of drill chips and reverse circulation drilling (RC) cores coupled with an AMD evaluation completed prior to a bulk sampling program.
- Implement a supplementary AMD study comprising mineralogical, ABA, NAG and hydro-geochemical assessments to verify the conceptual model.

The salient findings of these investigations are:

Chemical and Mineralogical Analysis

- Samples including drill chips and RC cores are dominantly iron-silicates with accessory MgO and Al_2O_3; relatively low concentrations of CaO are generally associated with phosphorous.
- Concentrations of S are predominantly low averaging 0.03% with the highest concentrations found in the ironstone sparse oolites with sporadic occurrences in shales, dolerites and sandstones.
- Sulfide bearing materials are encountered at an average depth of about 37m below ground level.
- The Geochemical-Abundance Indices (GAIs) of the samples indicate that 2,493 samples are rich in arsenic (up to about 96 fold); 2,539 samples are rich in iron (to about 12 fold); and about 270 samples are rich in sulfur (to about 24 fold).
- Pyrite (FeS_2) has been identified as the form of sulfide associated with siderite iron-silicate quartz hematite sandstone.

The Potential for Acid Formation (PAF) of the Bulk Samples

- Paste pHs range between 4.7 and 5.9 and are slightly acidic averaging at 5.3.

- 85% of samples (22 out of 26) are classified, on the basis of their sulfide-S concentrations and positive APRs, as non-acid forming (NAF) materials.
- 15% samples (4 out of 26) fall within the zone of uncertainty when comparing net acid generating (NAG) against NAPP or are classified as PAF materials based on the ANC/MPA ratio <1.

The preliminary findings of the chemical and mineralogical analysis and the assessment of the bulk samples guided the compilation of a mine waste rock/ore balance:

- In an overall mass balance of 212 million tons only 0.03% or 59,255 tons can be classified as having the potential to generate acidity.
- Most of the near-surface (<30m depth) materials across the mine pit possesses low S% values (<0.25%) and are classified as non-acid forming materials.

Conceptual Model

- Deposit C has a low likelihood of producing acid mine and metalliferous drainage.
- Sulfides occur sporadically and are highly localised, confined to below the floor of the proposed open pit.
- The majority (84%) of PAF materials occur outside the perimeters of the proposed open pit and/or are beneath the base thereof.
- The ground water level is likely to remain below the base of the open pit. Localised perched waters in shallow highly weathered and/or fracture systems are not of concern.
- Deep ground water may be impacted by infiltrating rain from the proposed backfilled pit migrating through the underlying natural/undisturbed PAF bodies.

Supplementary AMD Evaluation

- Seven existing RC cores were selected and twenty-one new AC bores were drilled for this assessment aimed at validating the conceptual model detailed above.
- Samples are composed of iron-silicate minerals with iron oxides such as hematite and goethite.
- The RC core samples are chemically dominated by iron, aluminium and potassium. Magnesium, manganese, phosphorous and sulfur are also present but only in trace quantities. The highest concentration of sulfur was found in the siltstones of sample RR0037D.
- Sulfide minerals were reported to be insignificant in the drill chip samples from the AC bores.
- Paste pHs range from 5.4 to 8.0 with an average pH of 6.4 (circumneutral). Electrical conductivity ranges from 8µS/cm to 105µS/cm with an average of 39µS/cm.
- The samples have sulfide concentrations ranging from 0.001% to 0.370% averaging 0.040%.
- The dolerite in AMDAC21 is the only sample classified as PAF. It has a low NAG pH of 3.8, a NAG (pH 7.0) of 11kgH_2SO_4/t, APR<1.0, relatively high amorphous minerals (26%) and carbon concentration (1.7%), but circumneutral paste pH.
- A large number of samples comprising ferruginous sandstones, sandstones, shales and quartzite have high APRs (>10) indicating these materials have elevated potentials to neutralize acidity.

In general:

- 24 out of 28 samples are classified as NAF with high APR (>10) indicating these materials have elevated potentials to neutralize acidity.
- 3 out of 28 samples are classified as uncertain, including samples RR0037D and RR049D (both siltstones) and RR0044D (ferruginous sandstone) with APRs <1.0 which reflects low buffering capacities.

- 1 out of 28 samples is classified as PAF: sample AMDAC21 (dolerite).

In essence the supplementary investigations validated the observations made and assessments arrived at during developing of the conceptual model.

The hydrogeochemical evaluation of these samples indicated:

- The average pH of leachates from 25 samples is predominantly circumneutral (6.5) with pH ranging between 5.4 and 7.8. The highest pH (7.8) is related to the deep beaded shales whilst the lowest are related to the ironstone sparse oolites and ferricrete sandstones located near the surface to 25m depth.
- The highest concentrations of sulfate (SO_4) and chloride (Cl) are produced by shales and siltstones from depths ranging between 25m and 42m below surface and correlate with slight decreases in pH.
- Major ions are in the order of magnesium>sodium>potassium>calcium indicating substantial activity of dolerite and iron silicate components.
- Trace metals are in the order of Fe>Al>Mn with no significant concentrations of toxic elements such as cadmium and/or chromium.
- Although arsenic is present in most samples, its mobility is very low with an average value of 2.22µg/L.
- The samples of shale, dolerite and ironstone sparse oolites produce HCO_3, Cl + SO_4 type leachates. The samples of siltstones, sandstones and ferruginous siltstones/sandstones produce Na + K type leachates.

Risk Assessment and Management Implications

The key risk relates to the potential for ground water that may be impacted by seepages (infiltrating rain) from within the backfilled open pits.

Ground water was not encountered, neither during exploratory drilling nor the subsequent drilling for the bulk sampling program, within the confines of the open pit. Mining is therefore unlikely to intersect ground water and consequently there will be no influx into the open pit. However, there is a potential for ground water to be impacted by infiltrating rain through the base of the open pit during mining and backfilling post closure. These potential seepages, infiltrating waters that may transport oxygen into prevailing anoxic environments, may migrate through natural undisturbed PAF bodies underlying the open pit. Nevertheless, PAF bodies are relatively small, isolated and largely confined to the north-west of the proposed open pit, whilst evaporation exceeds rainfall by several orders of magnitude which will limit the quantity of water that may infiltrate through the base of the open pit. Rain falling into the open pit may also be diverted away from areas where PAF bodies are known to exist in addition to more traditional measures to treat and manage PAF materials.

Further targeted assessments to ascertain the areal extent of PAF materials accurately, using mineralogical, ABA and hydrogeochemical studies, are to be undertaken during year 3 prior to mining the open pit in the north-west between years 4 and 6 to verify these findings and confirm the most appropriate measures for treating and managing excavated and exposed PAF materials.

A summary of the potential risks appear overleaf.

Management Implications:

- The management of areas with PAF materials should include:
  - Demarcation of the extent of the PAF materials, control and monitoring of excavated and exposed materials whilst mining the open pit.
  - Upfront engineering/scientific approaches to identify, predict, prevent, remediate and monitor potential AMD formation.
- Disturbance of PAF material at the north-western part of the proposed open pit will occur only when the

pit expands from 30m to 40m below surface. According to the proposed schedule, areas which contain PAF materials will be mined between years 4 and 6. Further site specific characterisation, prevention and remediation measures should be undertaken in year 3 or sooner if required.

- Methods to identify, treat and manage the potential for AMD formation during mining of Deposit C includes:
  - Further ABA sampling and assessment from 30m to 40m depth to verify the lateral and vertical extent of PAF materials during grade control.
  - Update the block model to improve waste rock/ore body delineation with regard to NAF/PAF characterisation.
  - NAF/PAF characterisation and demarcation where exposed in the base and walls of the open pit.
  - Materials from the area with PAF will be segregated and managed to prevent interaction with rainfall particularly.
  - PAF materials should be disposed of in purpose designed and built encapsulation cells, adequately covered and compacted.
  - Exposed PAF materials are to be covered by engineered and compacted covers using NAF materials.
- The conceptual design model for the disposal of PAF waste materials include:
  - Use excavated NAF materials to construct engineered beds and/or cells for the disposal by encapsulation of PAF materials.
  - Inhibition of oxygen and water into PAF materials is to be achieved by engineered compacted NAF covers.

Monitor ground water quality in shallow and deep bores up and downstream of the open pit.

Summary of Risk/Impact Assessment and Management Measures:

Impacts Acid Mine Drainage	Potential Risk	Comment/Proposed Control/Management Measures	Residual Risk
Open Pit Mining: Contamination of surface and ground water resources by infiltration of rainwater (with oxygen) from open pit into underlying PAF materials Expose/disturb/excavate PAF materials	L H	No stream diversions required. No mine influx and/or discharge. Demarcation by on-going assessment (mineralogical, ABA and hydro-geochemical testing) during grade control and selective mining. Immediate implementation of measures such as burial, encapsulation, cover systems and compaction to contain and prevent PAF materials to oxidise. Benching, where possible, in lengths that permit easy extraction, remediation and closure. Where PAF is exposed in pit walls, capping and compaction before back-filling. Implementation of construction methods to prevent long-term PAF exposure to oxygen (e.g. sheet piling). Construction of trenches in which PAF materials can be disposed of and covered; located preferably where backfilling can proceed immediately. Monitor effectiveness of covers and predict future conditions of the remediated materials. Water treatment, where and if required: daily monitoring of key parameters such as pH and acidity. If pH<5.0 with excess acidity, then neutralise solutions to pH (6.5 to 8.5) using agents such as calcite pellets, lime sands, etc. Removal of metals using suitable filtration or flocculation methods.	L L
Rehabilitation and Closure	L	Other than seasonal collection of rain water in rehabilitated open pits and subsequent evaporation and infiltration no permanent water bodies.	L
Notes: Rank: S denotes Significant, M Moderate and L Low.			

1. Introduction

1.1 Background

Pendragon Environmental Solutions Pty Ltd was engaged by EcOz Environmental Services, on behalf of Sherwin Iron Ltd, to undertake acid mine/metalliferous drainage (AMD) investigations and assessments across Deposit C at the Sherwin Creek Ore Project.

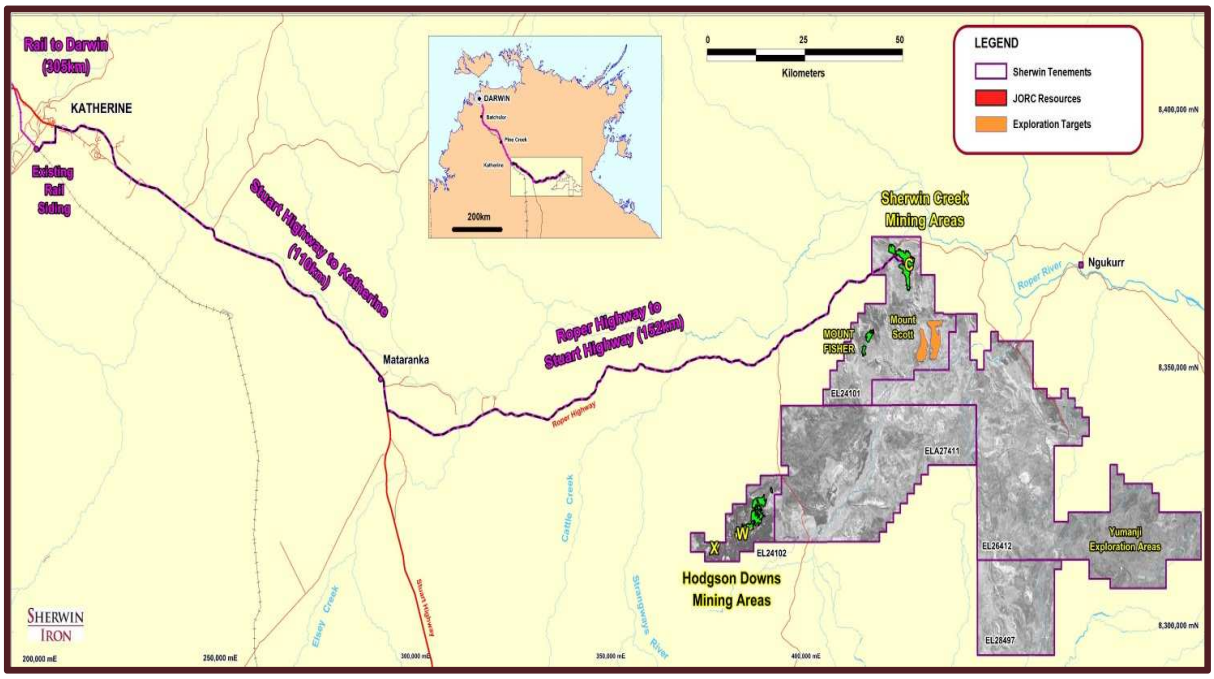

Figure 1: Sherwin Creek Iron Ore Project.

The project is located in the Northern Territory 450km south-east of Darwin and 120km east of Mataranka (Figure 1). It is accessible from the Stuart Highway, linking Darwin and Katherine, and the Roper Highway.

Sherwin Iron plans to commence DSO operations within the Sherwin Creek area (MLA29584) at Deposit C (Figure 1). This tenement lies within Exploration Licence EL24101 held in the name of Sherwin Iron (NT) Pty Ltd, which is a subsidiary company owned by Sherwin Iron Ltd.

The closest settlements are Mataranka, roughly 100km west, Ngukurr approximately 100km north-east and Minyerri 16km south. Ngukurr is the largest settlement in the region with a population of more than 1,500.

1.2 Objectives

The objectives for this study are:

- Characterise core rock and drill chip samples in terms of their potential for acid forming (PAF) and availability and/or enrichment of metals to the environment.
- Develop a conceptual model to ascertain the potential for acid metalliferous/mine drainage (AMD).
- Implement a sampling and analysis plan to verify the validity of the conceptual model.

- To ascertain the potential impacts on the surrounding environment and downstream surface and ground water resources.
- Assess the implications for mine operations with regard to waste rock management.

1.3 Scope of Work

The scope of work involved:

- A desktop assessment of available geological, geochemical and hydrogeochemical information and data gathered during exploration and bulk sampling investigations.
- Development of a conceptual site model indicating risks, opportunities, constraints and potential outcomes.
- Characterising acid producing potential (APP) in overburden, waste rock and ore materials.
- Assessment of likely impacts and risks to surface and ground water and surrounding downstream environment.
- Compiling a report with conclusions and recommendations.

2. Project Description

2.1 Brief Project Description

2.1.1 Resources

Sherwin Iron has been carrying out a series of exploration activities and studies for the Sherwin Creek Iron Ore Project: Deposit C in Exploration Lease EL24101:

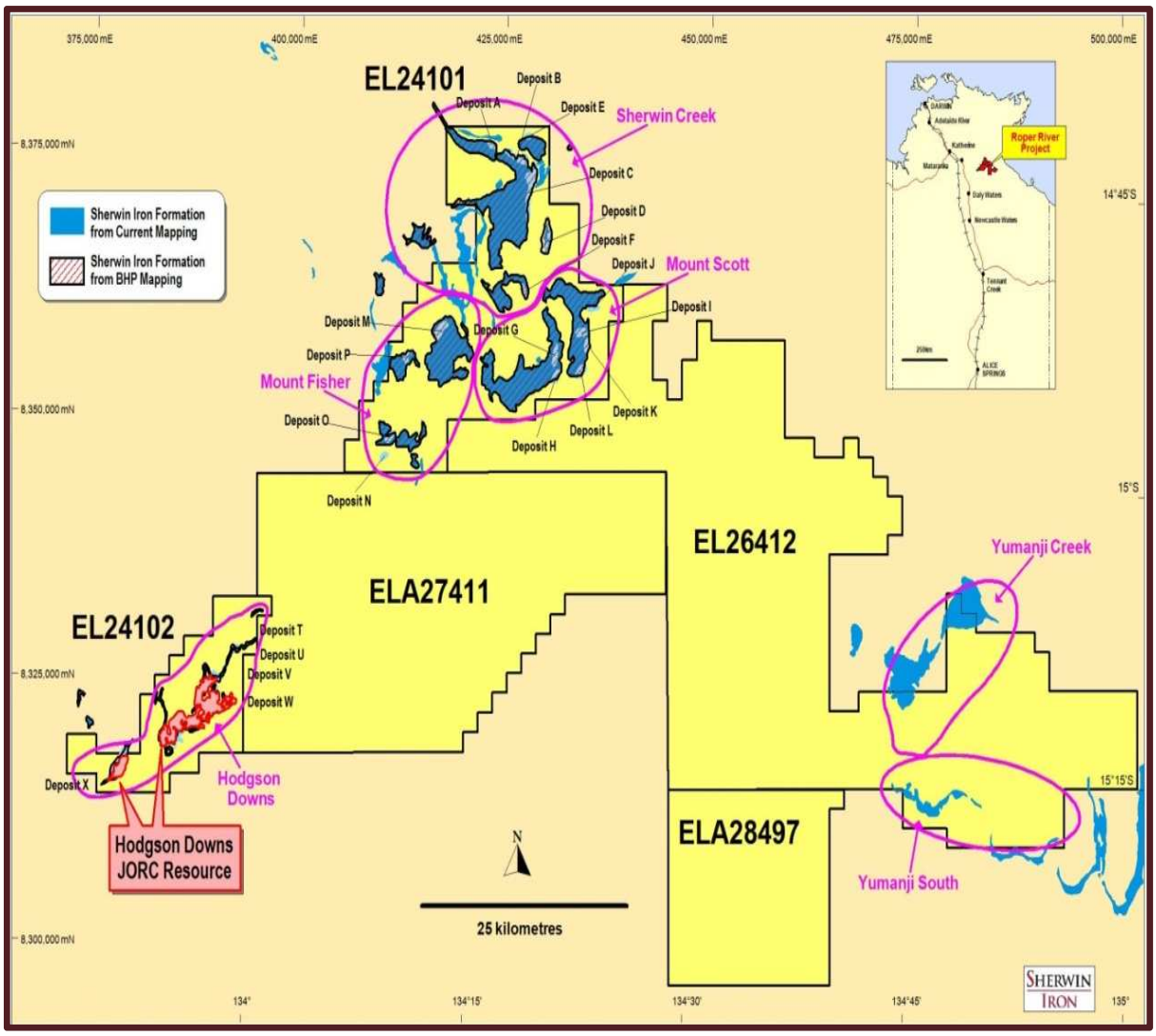

Figure 2: Mining Tenements.

The total global resource is 488Mt at 42.0% Fe including 320Mt at 40.1% Fe at Sherwin Creek (Deposits A, B, and C). The deposits comprise of large hematite-goethite iron ores and exploration confirmed other extensive high grade targets. Overall resources have been estimated as:

- HG (High grade) 57% Fe as Direct Shipping Ore (DSO).
- LG (Low grade) 52% Fe which can be beneficiated to 60% Fe based on current metallurgical testing.
- SG (Sub Grade) 40% Fe which is currently not saleable but may have a potential future value.

Current mining activities focus on Deposit C (Figure 3), Sherwin Creek (MLA 29584).

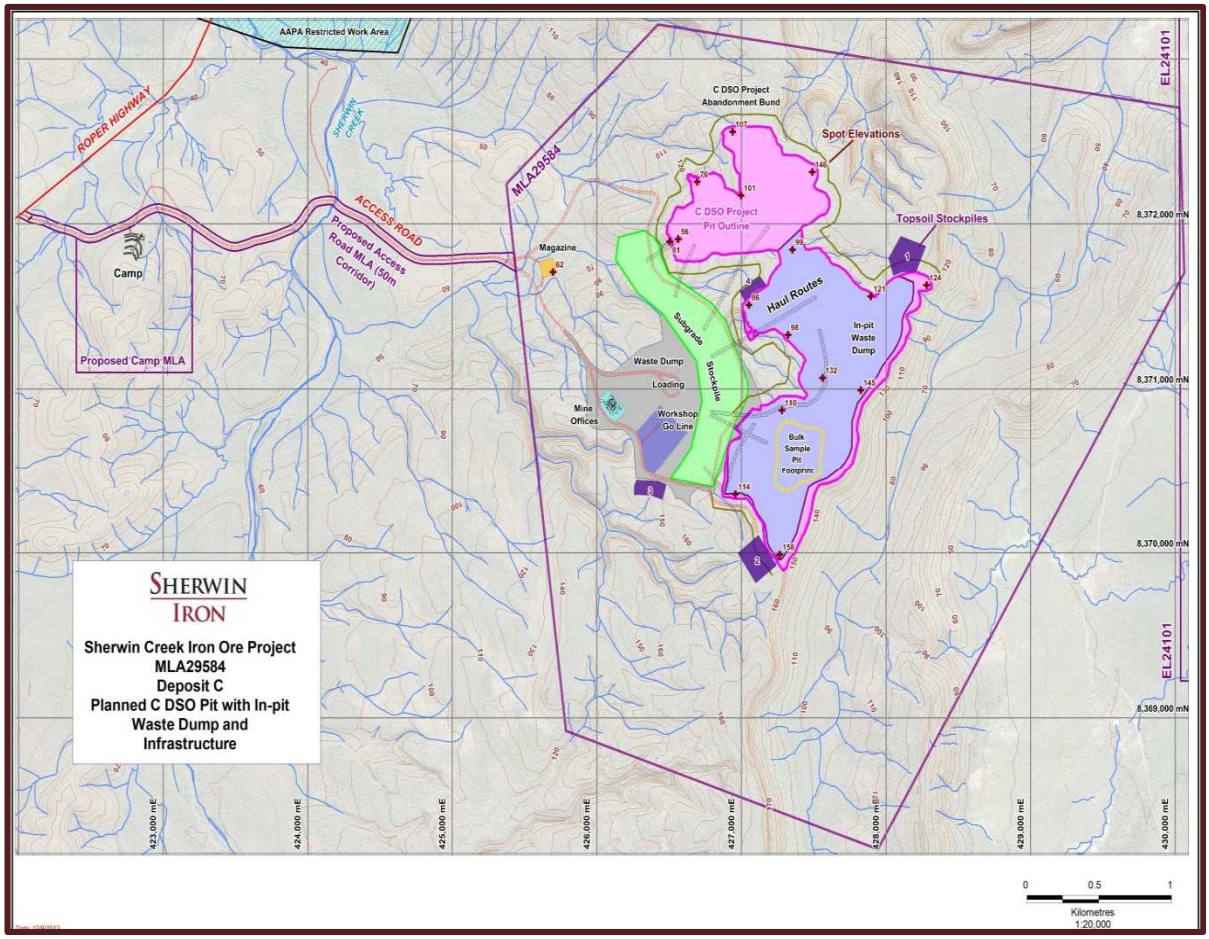

Figure 3: Deposit C DSO-Pit.

2.1.2 Regional Geology

Quartz sandstone with interbedded micaceous siltstone, mudstone, shale and locally ironstone of the Mesoproterozoic Roper Group are typical of the geology at the Sherwin Creek Iron Ore Project (Figure 4). These are situated on the flank of the east-west trending Urapunga tectonic ridge, separating the Batten and Walker troughs of the McArthur Basin. The area is also characterised by north-south trending faults of the Showell Fault Zone with some extending north-west to south-east and displaying a thrust component.

The mid-Proterozoic sequences of the Vizard, Nathan and Roper Groups dominate the broad regional geology in the area and are separated by unconformities. The Vizard Group is the lowest part of the MacArthur Basin outcropping within the regional area and comprises stromatolitic dolomites of the St Vidgeon formation, which are overlain by the Nagi formation of interbedded quartz sandstone and siltstones (Neumann *et al*. 2007). The highest part of the basin sequence outcropping are the Mantangula Formation, the Limmen Sandstone and the Mainoru Formation of the Roper Group.

Ironstones are prominent on the local stratigraphic level (Roper and Hodgson Iron Deposits), are deeply oxidised, and at high grades become soft and friable (associated with reduced silica) and appear dark purple in colour. In drainage areas west of Sherwin's main tenements, dolerites are mapped as extensive flat lying sheets of red soil regolith with remnant ilmenite. A variety of marginal, shallow and deeper marine shelf environments reflect alternating basin-wide sea level rises and falls. Tholeiitic dolerite and gabbro sills were emplaced throughout the Roper group soon after deposition ceased and before regional deformation.

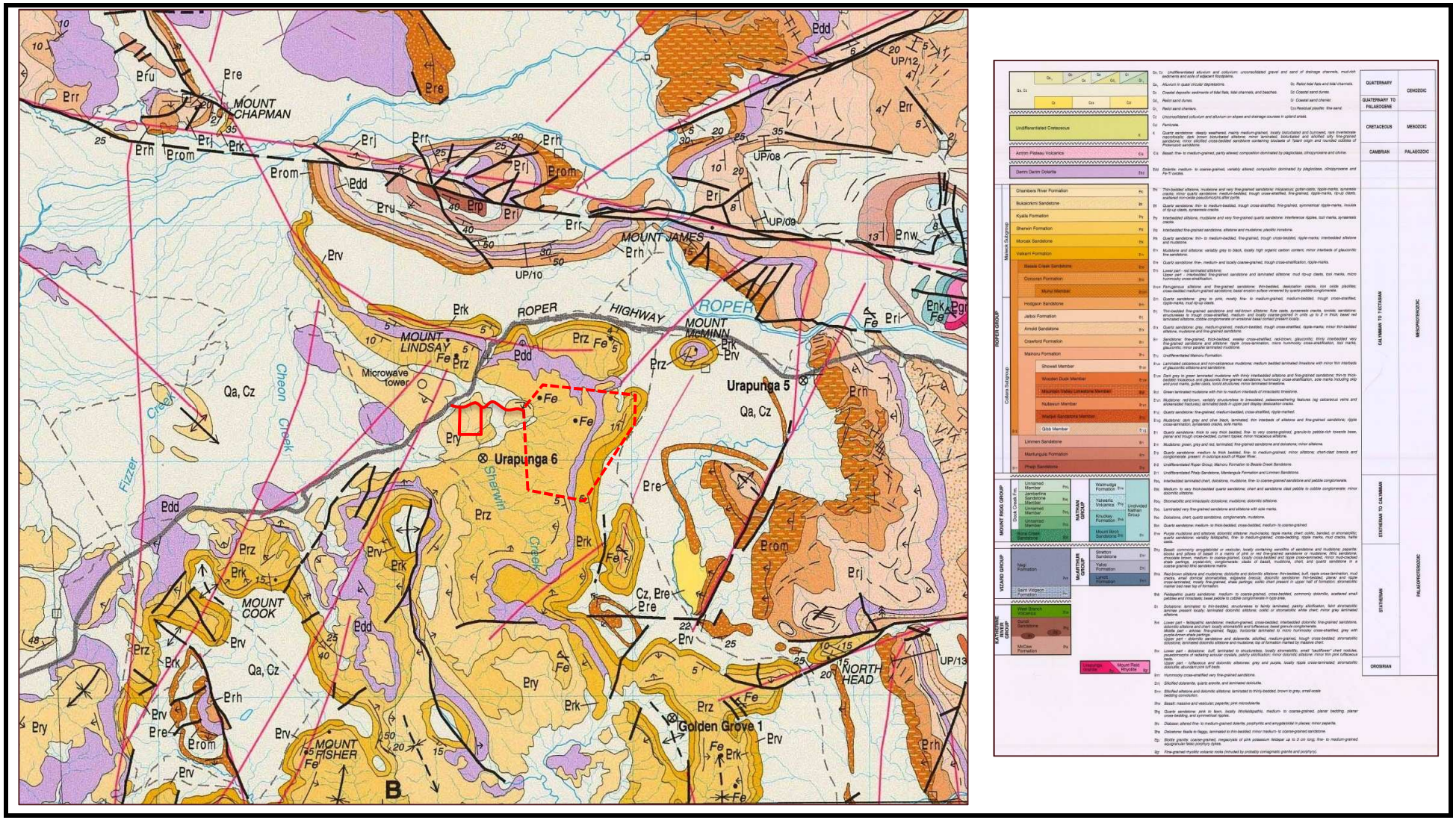

Figure 4: Regional Geology.

(Note: MLA29584 in dashed red lines)

2.1.3 Local Geology

The terrain is undulated with sandstone, siltstones and shale outcrops and covered by thin Quaternary soils. The cyclic sandstone and mudstone shallow marine sequence is up to 2,000m thick in the area and has been intruded by tholeiitic dolerite sills (Derim Derim Dolerite) prior to regional deformation. ML29584 (Deposit C) is contained within the Maiwok Sub Group, the upper part of the Roper Group stratigraphy, within this part of the Mesoproterozoic McArthur Basin. The stratigraphy of the Maiwok Sub Group within the tenement area includes the Velkerri Formation at the base. This is a mudstone and siltstone that is variably grey to black reflecting high carbon content.

Overlying the Velkerri Formation is the Moroak Sandstone, a quartz rich unit characterised by thin to medium bedding, fine grain size and interbedded with siltstone and mudstone. The sandstone is characterised by cross-bedding with ripple marks evident. The Sherwin Formation overlies this unit as an interbedded fine grained sandstone, siltstone and mudstone with pisolitic ironstone as distinct units (Figures 5 and 6). These iron ore units are at several stratigraphic levels within the sediments of the Roper Group.

The outcropping overlying Kyalla Formation is found in ML29584 and includes interbedded siltstone, mudstone and very fine grained quartz sandstone, often showing dessication cracks. Mudstone of the Sherwin Formation in addition to extensive pisolitic ironstone lenses can also be observed within ML29584. The Upper, Middle and Lower Ironstone beds, are well represented at Deposits A, B and C at Sherwin Creek. The upper hematitic ironstone unit is typically 1m to 2m thick, the middle unit is 8m to 12m thick and the highest Fe grade lower unit usually 6m to 8m thick (Figure 6). The dolerite sills, up to 50m or more in thickness, intruded between the lower ironstone and the overlying basal oolitic hematite unit (Figure 5). The dolerite outcrops as low-relief medium to coarse grained, variably altered and weathered rounded boulders. These dolerites are medium to coarse grained, variably altered, with composition dominated by plagioclase, clinopyroxene and Fe-Ti oxides.

The basal oolitic hematite unit is exposed and well represented at Sherwin Creek Deposit E, where it is typically only 1m to 2m thick and at Mt Fisher Deposit M, where it is usually 3m to 4m thick and high grade. In each case cliff faces display best exposures, with shallow dipping stratigraphy following topography away from the cliff faces.

2.2 EIS Requirements

On 18 December 2012, the Northern Territory Environment Protection Authority (NT EPA) determined that the Project requires formal assessment under the NT Environmental Assessment Act at the level of an Environmental Impact Statement (EIS). Issues of concern contributing to the decision included:

- the size and scale of the proposal;
- the potential impacts on biodiversity, including listed flora and fauna, from land clearing;
- activities and weed incursion as a result of the development;
- uncertainties regarding in-pit rejects disposal and rehabilitation of the mine areas;
- **the unknown potential for acid and metalliferous drainage**;
- uncertainties associated with water resources and the potential impacts from the water supply dam;
- the potential adverse changes and disturbance to riparian corridor habitats, aquatic habitats and other currently unknown habitats from construction of the haul roads; and
- the potential social, cultural and economic impacts.

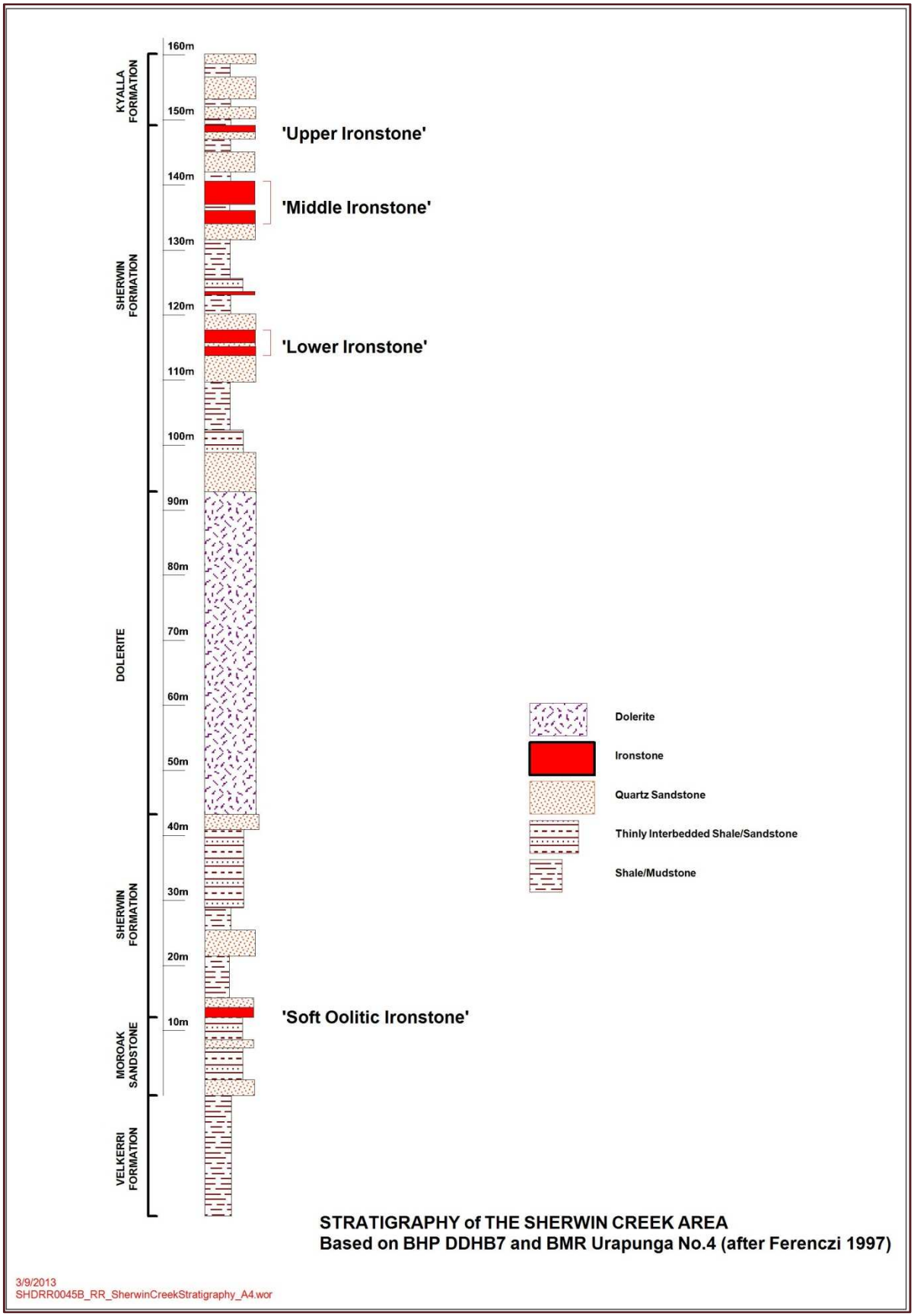

Figure 5: Stratigraphy at Sherwin Creek.

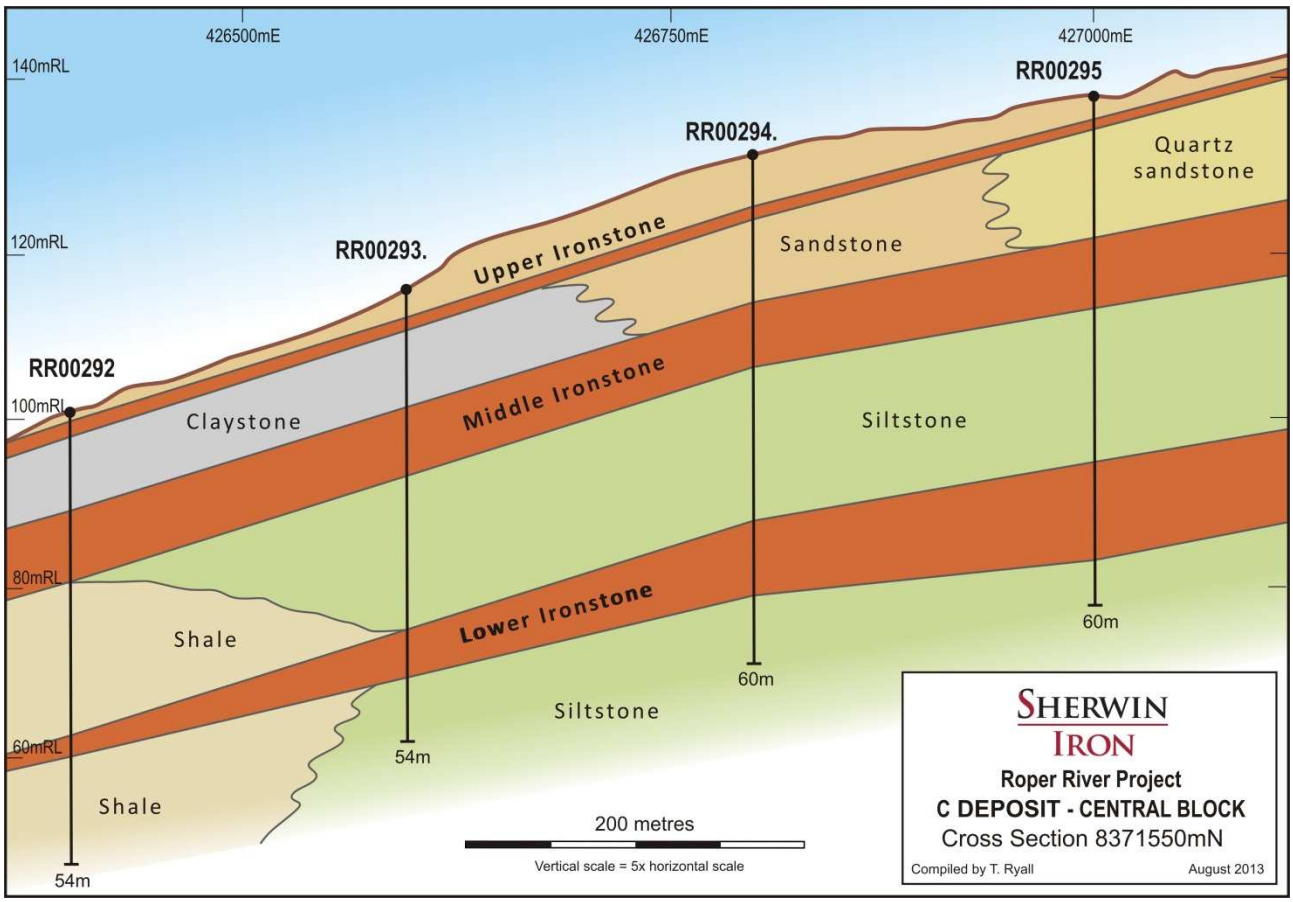

Figure 6: Cross Section – Central Block, Deposit C.

Furthermore, the NT EPA listed as a key risk:

- *water quality may be impacted by spills to surface water and runoff containing acidic leachate, hazardous substances or elevated sediment concentrations;*

and requested further information on the *potential impacts to surface and ground water systems from spills, leachate from potential acid forming waste material and sediment loads in stormwater runoff*. This would require assessment with regards to *mitigation strategies for ongoing geo-characterisation of waste rock and management of any potential acid forming material to prevent/minimise and manage acid and metalliferous mine drainage*.

Information requirements necessitated an investigation on "*the physical, geo-mechanical and chemical properties of the ore body with respect to rehabilitation characteristics such as slope stability, presence of potential acid forming material and vegetation establishment*. The findings of such an investigation are expected to *identify and discuss environmental risk associated with potential acid forming materials* and, if required, develop remediation and rehabilitation measures.

3. Methodology

3.1 Study Rationale

The assessment of the potential for AMD potential of the overburden, waste rock and ore materials at Deposit C followed a two way investigation approach:

- Develop a conceptual model based upon a mineralogical assessment of about 2,500 samples of drill chips and reverse circulation drilling (RC) cores coupled with an AMD evaluation completed prior to a bulk sampling program.
- Implement a supplementary AMD study comprising mineralogical, ABA, NAG and hydro-geochemical assessments to verify the conceptual model.

Geochemical methods used in this assessment are detailed below.

3.1.1 Mineralogical Evaluation

Various methodologies including X-ray microanalysis using energy-dispersive x-ray spectro-meters with scanning electron microscopy (SEM/EDX), X-ray diffraction (XRD) to identify mineral forms and modal composition, X-ray fluorescence (XRF) to define total concentration of minerals in the solid phase and petrographic analysis to principally determine the physical and chemical characteristics of the materials, are the most common mineralogical analyses used.

XRF data is normally used to calculate the geochemical abundance index (GAI, Förstner et al., 1993) of the samples to indicate potential enrichment by major elements (Table 1):

$$GAI = \log[(C_n/(1.5*B_n)),2]$$

where C_n is the measured content of the n^{th} element in the sample and B_n is the average-crustal-abundance of the element.

Table 1: Geochemical Abundance Index and Significance.

GAI	Symbol	Relevance
0	AC	The content of the element is less than, or similar to, the average-crustal-abundance.
1	3F	A 3 - fold enrichment above the average-crustal-abundance.
2	6F	A 6 - fold enrichment above the average-crustal-abundance.
3	12F	A 12 - fold enrichment above the average-crustal-abundance.
4	24F	A 24 - fold enrichment above the average-crustal-abundance.
5	48F	A 48 - fold enrichment above the average-crustal-abundance.
>6	96F	A 96 - fold, or greater, enrichment above the average-crustal-abundance.

3.1.2 ABA and NAG Assessment

The Potential for Acid Formation (PAF) is assessed by determining the pH of paste solutions, oxidation pH, Total-S, acid-neutralization capacity (ANC) and net-acid generation (NAG).

Whilst ABA and NAG tests have limitations, both tests in combination increase the reliability of acid generation prediction in waste and ore materials (DITR, 2007). The tests selected for this assessment are widely used and accepted methodologies for the geochemical characterisation of mine waste materials (Alarcón León, 2012; INAP, 2011; DITR, 2007 and NTMC, 2004).

3.1.3 Calculated Parameters

The Maximum Potential Acidity (MPA) values (in kgH_2SO_4/t) of the samples were calculated by multiplying the Sulfide-S values (in %) by 30.6. The multiplication factor of 30.6 accounts for the reaction stoichiometry for the complete oxidation of pyrrotite and pyrite by O_2 to $Fe(OH)_3$ and H_2SO_4.

The Net Acid Producing Potential (NAPP) values (in kgH_2SO_4/t) were calculated from the corresponding MPA and Acid Neutralisation Capacity (ANC) values: NAPP = MPA - ANC. The acid potential ratios (APR) were calculated from the relationship of ANC/MPA.

A more conservative acid potential ratio (APR) criteria for the NAF Category reflects the need to compensate for the availability of alkalinity forms for neutralisation of acid produced through pyrite-oxidation. The international approach generally define a sample with the likely potential to produce acidity if 1≤APR≤2 (Jambor, 2003); however this assessment relates to whether ANC and MPA are calculated *free of errors* and to local conditions with regard to sulfide form, morphology and concentrations.

3.1.4 Classification Criteria

Table 2 lists the most accepted criteria for classifying PAF of mine waste materials. In many cases NAPP values are site specific and this would depend on the sulfide form and morphology and potential buffering capacity of samples.

Table 2: AFP Classification Criteria.

Category	DITR, 2007	Lei and Watkins, 2005	OSS-ACMRR*-DITR
Non-Acid Forming (NAF):	Sulfide-S < 0.3% For Sulfide-S ≥ 0.3%, a negative NAPP value and APR ≥ 2.0	NAPP < -20 APR >3	NAG-pH > 4.5 NAG <5-10
Potentially Acid Forming PAF):	For Sulfide-S ≥ 0.3%, any positive NAPP value, negative NAPP value with an APR < 2.0	NAPP > 20 APR < 1	NAG-pH <4.5 NAG > 10
Zone of Uncertainty	NAPP: between -20 and +20; APR: between 1 and 3		
*Office of the Supervising Scientist and the Australian Centre for Mine Rehabilitation Research.			

Lithotypes with Sulfide-S concentrations less than 0.3% are unlikely to oxidise at rates fast enough to result in acidification (pH less than 4.0 to 5.0). Criteria in Table 2, which reflects field experiences in Australia and includes an APR>1 (to sometimes 3), in addition to a cut-off NAG-pH value of 4.5 (Table 3), was employed in the current assessment to classify the AFP of the samples.

Table 3 details the international and national approaches to NAG classification:

Table 3: NAG Classification Criteria.

NAG pH	NAG (kgH_2SO_4/t)	Geochemical Classification
≥ 4.5	0	Non-Acid Forming (NAF)
<4.5	≤ 5	Potentially Acid Forming (PAF)
<4.5	>5-10	Potentially Acid Forming (PAF)

4. Deposit C Conceptual Model

4.1 Mineralogical Evaluation

4.1.1 Number of Samples

A total of 2,541 samples from drill chips and RC cores, between surface and 55m depth, were assessed for their chemical content (Table 4 and Figure 7). Most samples were attained at an average depth of 19m below surface within the middle ironstone unit (Figures 5 and 6).

Table 4: Minerals associated with Overburden, Wastes Rocks and Ore.

Mineral	Unit	Average	Median	Maximum	Minimum	No samples
SiO_2	%	28.1	27.5	77.6	0.001	2,540
Al_2O_3	%	1.7	1.0	12.3	0.001	2,540
CaO	%	0.04	0.03	0.30	0.001	887
K_2O	%	0.04	0.02	1.20	0.001	2,276
MgO	%	0.25	0.06	3.20	0.001	2,385
Na_2O	%	0.02	0.02	0.30	0.001	1,283
TiO_2	%	0.05	0.02	0.50	0.001	2,483
Fe	%	46	47	66	0.001	2,540
P	%	0.006	0.005	0.043	0.001	1,771
S	%	0.027	0.013	0.845	0.001	2,535
As	ppm	109	100	300	0.001	2,494
Ba	ppm	160	100	1,210	0.001	595
Cl	ppm	234	100	1,750	0.001	1,396
Sr	ppm	7.4	7.0	39.0	0.001	25
V	ppm	45	44	72	32	11
Zn	ppm	25	18	100	12	12
Zr	ppm	134	150	160	100	11

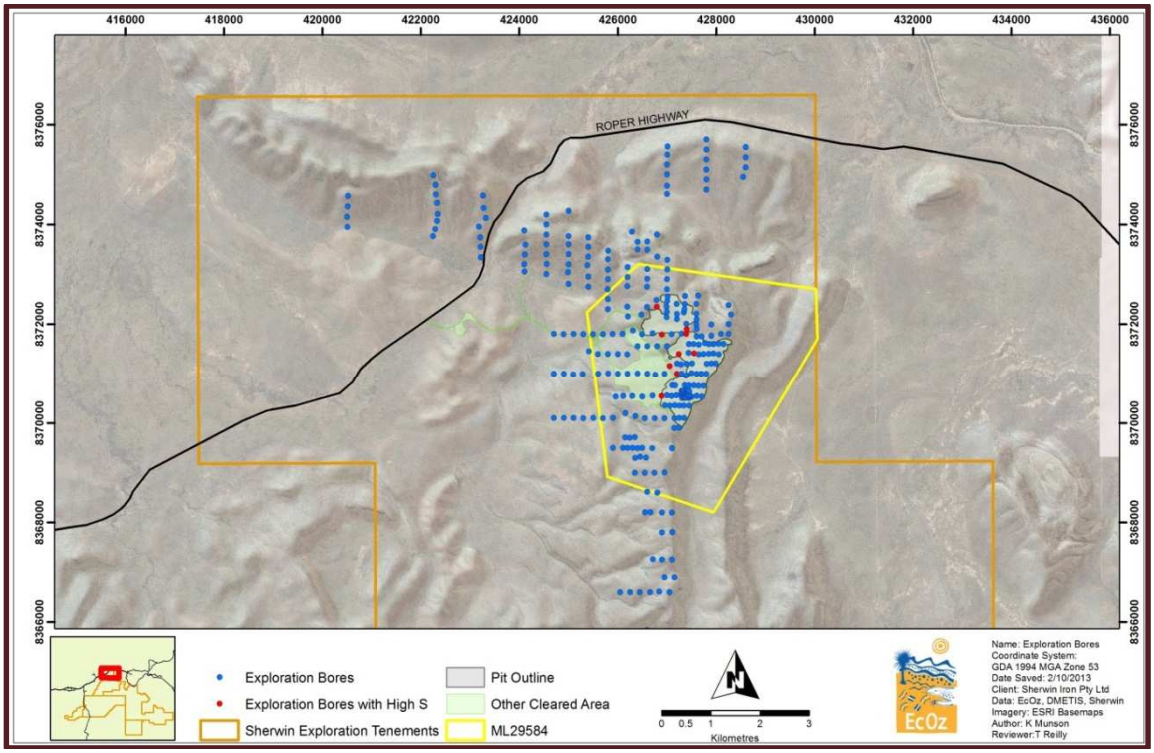

Figure 7: Location of Exploration Bores at Deposit C.

4.1.2 XRF Assessment

The XRF method subjects the sample to short wavelength X-rays which induce emission of longer wavelength X-rays from the sample. The elements present and their concentrations are determined by identification of their characteristic X-ray spectra (Lapakko, 2002). However, the sensitivity and detection limits of the method are dependent on the rock matrix. Assay whole-rock major and selective trace-element analyses of the samples are summarised in Table 4 (the data set is included in Appendix A).

The resulting chemistry indicates that mineralogy of the samples is dominantly iron-silicates with accessory MgO and Al_2O_3. Although at relatively low concentrations CaO is generally associated with phosphorous. Whilst the dominant mineral is Fe (~45.7%>S>P), major minerals associated with oxides are in the order of SiO_2>Al_2O_3>MgO.

Concentrations of S are predominantly low and have an average value of 0.03% ranging between 0.001% and 0.845%. Although the highest concentration of S (0.845%) was found in a deep shale sequence, large concentrations of S occur generally in the ironstone sparse oolites with sporadic occurrences in shales, dolerites and sandstones (Table 5 and Figure 7). About 56% of these samples (from four bores RR00289, RR00306, RR00425 and RR00444), are located beneath the DSO body. The remaining 44% of the samples (from five bores) are within areas where DSO will be removed. On average sulfide bearing materials are encountered at a depth of about 37m below surface.

Table 5: Highest S Concentrations in Relation to Lithology and Depth.

Hole - ID	Coordinates		Open Pit C	Depth (mBGL)		Lithology	S
	Eastern	Northern	DSO	From	To		%
RR00046	427201.0	8370997	In	37	38	Sst	0.325
RR00289	426899.8	8371791	In	40	41	Shl	0.397
RR00289	426899.8	8371791	Below	51	52	**Shl**	**0.845**
RR00301	427058.6	8371156	In	33	34	Irs	0.345
RR00306	426892.5	8370549	Below	35	36	Slt	0.442
RR00425	427241.7	8371399	Below	36.5	37	Irs	0.547
RR00425	427241.7	8371399	Below	37	37.5	Irs	0.356
RR00425	427241.7	8371399	Below	44.5	45	Irs	0.385
RR00425	427241.7	8371399	Below	45	45.5	Irs	0.513
RR00435	427550.8	8371415	In	35	35.5	Irs	0.463
RR00435	427550.8	8371415	In	35.5	36	Irs	0.576
RR00443	427394.4	8371808	In	36.5	37	Dol	0.304
RR00443	427394.4	8371808	In	37	37.5	Irs	0.354
RR00443	427394.4	8371808	In	39	39.5	Irs	0.562
RR00443	427394.4	8371808	In	39.5	40	Irs	0.548
RR00444	427402.6	8371902	Below	26	26.5	Irs	0.400
RR00444	427402.6	8371902	Below	26.5	27	Irs	0.380
RR00444	427402.6	8371902	Below	27	27.5	Irs	0.454
RR00444	427402.6	8371902	Below	28	28.5	Irs	0.457
RR00444	427402.6	8371902	Below	28.5	29	Irs	0.597
RR00444	427402.6	8371902	Below	29	29.5	Irs	0.394
RR00444	427402.6	8371902	Below	30	30.5	Irs	0.338
RR00451	426798.4	8372353	In	47	47.5	Irs	0.368

In denotes S concentrations within the ore body and/or project area; **Below** denotes beneath the DSO, **Shl:** shales; **Sst** sandstones; **Slt** Siltstone; **Dol** dolerite and **Irs** for ironstone sparse oolites.

4.1.3 Multi-Element Analysis

A summary of sample enrichment, as indicated by the values of the Geochemical-Abundance Index (GAI), is presented in Table 6. Except for enrichment by iron and arsenic, most of the samples are not distinctively enriched with any particular element. Whilst enrichment by arsenic is observed in 2,493 samples, enrichment by iron to about 12 fold is observed in 2,539 samples. The highest iron enrichment is typical in the ironstone sparse oolites at depths between 10m and 40m. Enrichment with S (to about 24 fold) was observed in about 270 samples, particularly among the ironstone sparse oolites (RR00444 and RR00435) and dolerites (RR00443) at depths between 20m and 40m. Most of these samples are also enriched by arsenic to about 96 fold.

Table 6: Summary of Mineral Enrichment (GAI).

	Fe	S	As	Ba	Cl	Co	Mo	Ni	Pb
Average	2.38	1.05	5.27	0.40	1.51	0.73	0.73	0.67	1.86
Maximum	2.97	3.51	6.80	0.92	3.01	0.73	1.74	0.67	2.25
Minimum	0.07	0.01	2.89	0.03	0.02	0.73	0.15	0.67	1.25
Number of Samples	2539	270	2493	13	373	1	11	2	18

4.1.4 Petrographic Assessments

The form of sulfide identified by petrographic analysis is pyrite which is associated to siderite iron-silicate quartz hematite sandstone. This exists as a trace form in a likely matrix/cement environment (Table 7) and would likely be locally disseminated.

Table 7: Petrographic Assessment.

Sample ID	Depth (m)	Mineral Composition		Classification
RR00125D	8.9	**PELLETOIDS**	**DOMINANT**	Quartz Hematite Pelletoidal Ironstone
		Hematite	*Dominant*	
		Quartz	*Minor*	
		Goethite	*Accessory*	
		Kaolinite?	*Trace*	
		MATRIX	**MAJOR**	
		Hematite	*Dominant*	
		Quartz	*Major*	
RR0034D	34	**SANDS**	**DOMINANT**	Quartz Hematite Sandstone
		Hematite	*Dominant*	
		Quartz	*Major*	
		MATRIX	**ACCESSORY**	
		Hematite	*Dominant*	
		Magnetite	*Trace*	
		Quartz	*Trace*	
		Clay?	*Trace*	
WO2		**PELLETOIDS**	**DOMINANT**	Quartz Hematite Pelletoidal Ironstone
		Hematite	*Dominant*	
		Quartz	*Minor*	
		Goethite	*Trace*	
		Clay	*Trace*	
		MATRIX	**MAJOR**	

Sample ID	Depth (m)	Mineral Composition		Classification
		Hematite	*Dominant*	
		Quartz	*Accessory*	
		Goethite	*Trace*	
		Clay?	*Trace*	
RR00364D	43	**SANDS**	**DOMINANT**	Siderite Iron-Silicate Quartz Hematite Sandstone
		Hematite	*Dominant*	
		Quartz	*Major*	
		Iron Silicate	*Minor*	
		Siderite	*Accessory*	
		Rutile	*Trace*	
		MATRIX/CEMENT	**MINOR**	
		Hematite/Magnetite	*Major*	
		Quartz	*Major*	
		Siderite	*Major*	
		Iron Silicate	*Minor*	
		Pyrite	*Trace*	
RR00240D	7.3	**PELLETOIDS**	**DOMINANT**	Chamosite Quartz Hematite Pelletoidal Ironstone
		Hematite	*Dominant*	
		Quartz	*Major*	
		Rutile	*Trace*	
		K-Feldspar	*Trace*	
		Biotite	*Trace*	
		MATRIX	**MAJOR**	
		Hematite	*Major*	
		Chamosite	*Major*	
		Quartz	*Accessory*	
X01		**OOIDS**	**DOMINANT**	Quartz Hematite Oolitic Ironstone
		Hematite	*Dominant*	
		Quartz	*Major*	
		Goethite	*Accessory*	
		Kaolinite	*Trace*	
		MATRIX	**MAJOR**	
		Hematite	*Dominant*	
		Goethite	*Minor*	
		Quartz	*Accessory*	
		SECONDARY OVERPRINT	**ACCESSORY**	
		Hematite	*Dominant*	
		Goethite	*Major*	

4.1.5 XRF Base PAF/NAF Characterisation

The oxidation of sulfide minerals within a mining environment is generally regarded as a risk. However, depending on their iron concentrations and their hydrolysis phases, not all sulfide minerals produce acidity but may contribute to the generation of acid metalliferous drainage. Important base metal minerals such as sphalerite and galena only react to produce acidity when Fe significantly substitutes the metal component of the minerals (Rimstidt *et al.*,1994).

This indicative NAF/PAF assessment assumes that the concentration of S (%) in all representative samples is in the form of pyrite (FeS_2). Depending on the geochemical characteristics of the site, pyrite in contact to the media has the potential to produce acidity. Thus, the characterisation approach presented in Section 3.1.4, particularly with reference to sulfide concentration, classifies the samples as:

Table 8: Indicative NAF/PAF Characterisation based on Total-S Concentration.

	Core/Chips	PAF	NAF	UC
Total Samples	2,541	22	2,510	9
Percentage	100%	0.9%	98.8%	0.3%

Whilst only 22 from a total of 2,541 samples can be characterised as PAF materials (S>0.3%), the great majority of samples with a total of 2,510 can be classified as NAF materials (S<0.25%). Only 9 samples (S = 0.251% to 0.299%) are considered within the uncertain (UC) field (Table 8). As indicated in Section 4.1.2 above, these higher S-bearing materials are normally confined to areas below to recoverable ore bodies.

4.2 ABA Assessment for Bulk Sampling

4.2.1 Results

Sherwin Iron, following approval of a mining management plan (MMP), currently extracts a 200,000t bulk sample of DSO. The bulk sampling program included an ABA assessment of 26 samples collected across the entire bulk sampling pit (Figure 8).

The Potential for Acid Formation (PAF) of all waste rock materials within the bulk sampling area was assessed by determining the pH of paste solutions, oxidation pH, Total-S, acid-neutralization capacity (ANC) and net-acid generation (NAG) (Table 9).

Assessment of the samples indicated:

- Paste pHs are slightly acidic with an average of 5.3, ranging between 4.7 and 5.9. These results suggest that there is little or no freely available acidity in the samples.
- ABA classifications, with regard to sulfide as S concentration only, indicate that all samples are non-acid forming (NAF) materials.
- Because of low concentrations of S in the samples, it is assumed that an ANC/MPA ratio <1 is indicative of a rock to *likely* produce acid. Some 4 samples can be classified with a *likely* potential to produce acidity on this basis.
- A negative NAPP indicates that a sample has a net-neutralising capacity and a positive NAPP (>20kg H_2SO_4 equiv./t) indicates that a sample has a net-acid generating capacity. Thus no samples (those with positive APR) have the potential to produce acidity.
- NAG pH <4.5 indicates that rocks are likely to produce acidity. None of the samples produced low NAG pH.
- NAG pH and NAG pH 7.0 classifications indicate none of the samples has the potential to produce acidity (Table 9).
- When samples are assessed comparing NAG against NAPP, there is some discrepancy as 4 samples are within the positive NAPP uncertain (UC) area. However none of the samples were considered as PAF (Figure 9).

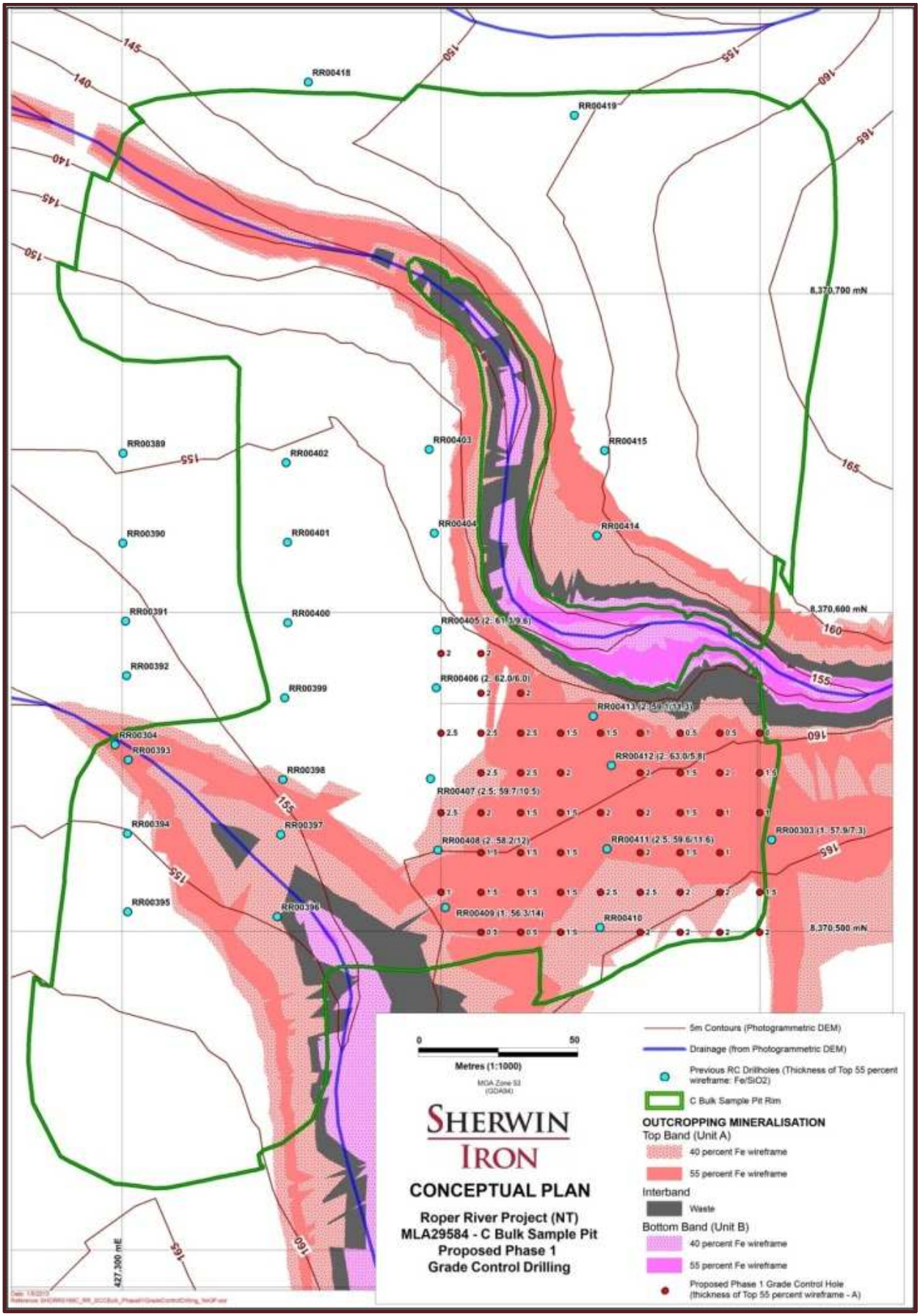

Figure 8: Bulk Sampling Pit and Bore/ABA Sample Locations.

Table 9: ABA/NAG Assessment.

Sample ID	Project Code	S	Paste pH	NAG_pH	NAG (pH7.0)	MPA	ANC	NAPP	APR	ABA Classification			Overall ABA/NAG Classification
		%	units	units	kg/T H_2SO_4	kg H_2SO_4 equiv./t				Based on %S	Based on APR	Based on NAG	
RRAMD_001	SHD119	0.01	5.20	9.6	<0.01	0.306	<0.01	0.30	0.03	NAF	PAF	NAF	UC
RRAMD_002	SHD119	0.03	5.20	8.5	<0.01	0.918	<0.01	0.91	0.01	NAF	PAF	NAF	UC
RRAMD_003	SHD119	0.04	5.20	9.3	<0.01	1.224	1.65	-0.43	1.35	NAF	NAF	NAF	NAF
RRAMD_004	SHD119	0.01	5.70	7.2	<0.01	0.306	0.37	-0.06	1.21	NAF	NAF	NAF	NAF
RRAMD_005	SHD119	0.03	5.30	9.4	<0.01	0.918	2.94	-2.02	3.20	NAF	NAF	NAF	NAF
RRAMD_006	SHD119	<0.01	5.00	9.6	<0.01	<0.01	0.78	-0.77	78.00	NAF	NAF	NAF	NAF
RRAMD_007	SHD119	0.02	5.00	7.7	<0.01	0.612	1.31	-0.70	2.14	NAF	NAF	NAF	NAF
RRAMD_008	SHD119	0.04	4.80	8.9	<0.01	1.224	1.7	-0.48	1.39	NAF	NAF	NAF	NAF
RRAMD_009	SHD119	<0.01	4.70	8.4	<0.01	<0.01	0.71	-0.70	71.00	NAF	NAF	NAF	NAF
RRAMD_010	SHD119	<0.01	5.10	7.5	<0.01	<0.01	1.99	-1.98	199.00	NAF	NAF	NAF	NAF
RRAMD_011	SHD119	0.03	4.70	9.4	<0.01	0.918	0.83	0.09	0.90	NAF	PAF	NAF	UC
RRAMD_012	SHD119	<0.01	4.90	8.7	<0.01	<0.01	1.39	-1.38	139.00	NAF	NAF	NAF	NAF
RRAMD_013	SHD119	0.01	5.90	8.2	<0.01	0.306	1.89	-1.58	6.18	NAF	NAF	NAF	NAF
RRAMD_014	SHD119	0.02	5.90	9.2	<0.01	0.612	2.09	-1.48	3.42	NAF	NAF	NAF	NAF
RRAMD_015	SHD119	0.01	5.10	7.3	<0.01	0.306	2.11	-1.80	6.90	NAF	NAF	NAF	NAF
RRAMD_016	SHD119	0.02	4.80	9.6	<0.01	0.612	1.48	-0.87	2.42	NAF	NAF	NAF	NAF
RRAMD_017	SHD119	<0.01	4.80	9.6	<0.01	<0.01	1.46	-1.45	146.00	NAF	NAF	NAF	NAF
RRAMD_018	SHD119	0.01	5.40	9.7	<0.01	0.306	0.01	0.30	0.03	NAF	PAF	NAF	UC
RRAMD_019	SHD119	<0.01	5.80	9.5	<0.01	<0.01	0.22	-0.21	22.00	NAF	NAF	NAF	NAF
RRAMD_020	SHD119	<0.01	5.80	9.5	<0.01	<0.01	1.65	-1.64	165.00	NAF	NAF	NAF	NAF
RRAMD_021	SHD119	<0.01	5.90	7.3	<0.01	<0.01	2.23	-2.22	223.00	NAF	NAF	NAF	NAF
RRAMD_022	SHD119	0.02	5.20	7.7	<0.01	0.612	1.63	-1.02	2.66	NAF	NAF	NAF	NAF
RRAMD_023	SHD119	<0.01	5.30	9.8	<0.01	<0.01	1.97	-1.96	197.00	NAF	NAF	NAF	NAF
RRAMD_024	SHD119	0.02	5.20	9.3	<0.01	0.612	0.78	-0.17	1.27	NAF	NAF	NAF	NAF
RRAMD_025	SHD119	<0.01	5.80	9.2	<0.01	<0.01	1.6	-1.59	160.00	NAF	NAF	NAF	NAF
RRAMD_026	SHD119	<0.01	5.50	8.9	<0.01	<0.01	3.06	-3.05	306.00	NAF	NAF	NAF	NAF

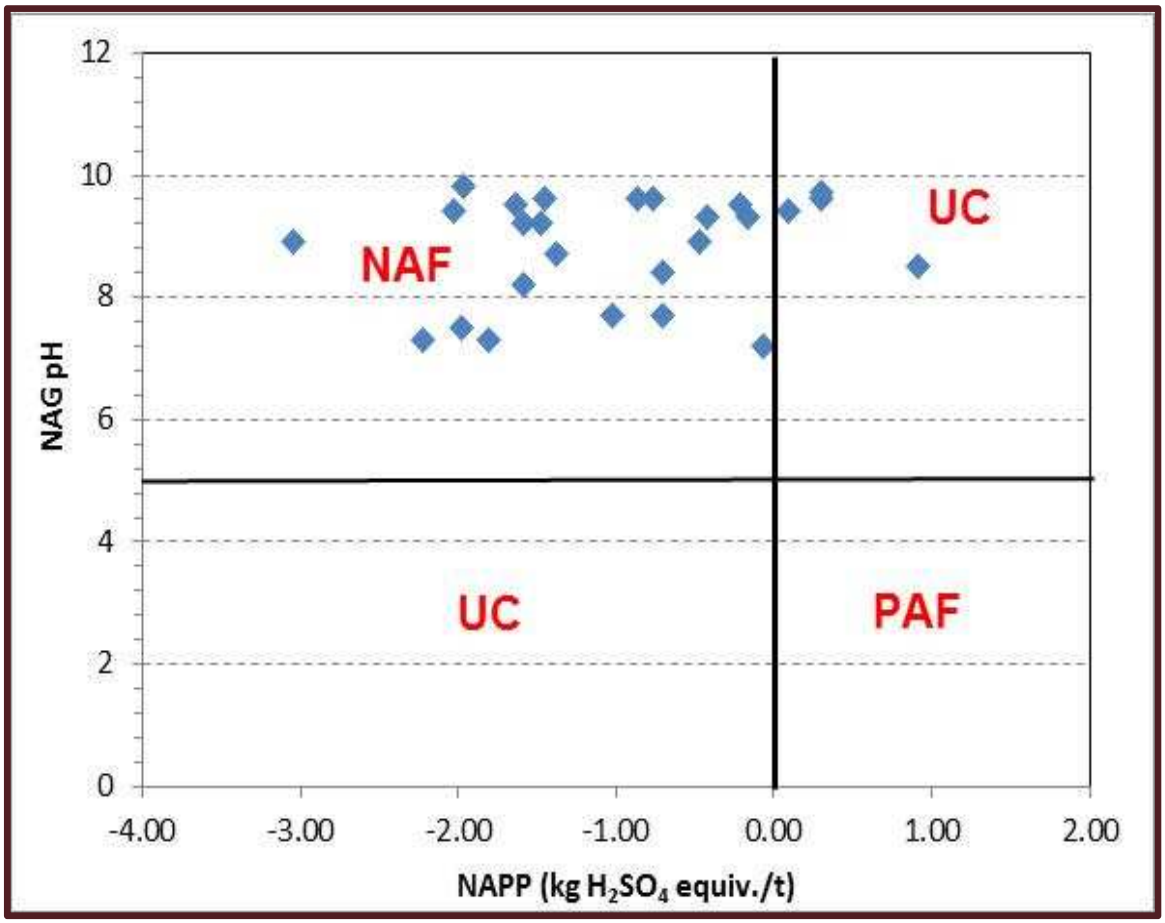

Figure 9: NAPP-NAG pH Classification.

4.2.2 Observations on the Bulk Sampling ABA Program

Observations from the Bulk Sampling ABA program and assessment include:

- The majority of the samples (85%) can be classified as non-acid forming (NAF) materials.
- Owing to the apparent conflicting results between NAPP and NAG results, only 4 out of 26 samples; i.e. 15%, are classified uncertain and requires further assessment.
- Materials classified as PAF, based on the APR assessment only, have low buffering capacities and therefore requires further assessment to improve the characterisation of both their acid forming and buffering potentials.

4.2.3 Mine Waste Rock/Ore Balance

An indicative waste rock-ore balance of acid- (Total S>0.25%) and alkaline-producing materials is presented in Table 10.

The indicative mass balance shows that:

- In an overall mass balance only 0.03% (or 59,255t) of materials can be classified with the potential to produce acidity.
- Most of the near-surface materials to a depth of about 30m across the open pit exhibited low S% (<0.25%) values and therefore can be classified as non-acid forming materials.

Table 10: Indicative Waste Rock/Ore Balance.

S (%) Ranges	Characterisation	Waste Rock			Average Concentrations	
		Volume	Tons	%	Fe %	S %
0.00 -> 0.05	NAF	85,977,607	199,084,411	93.81	13.97	0.01
0.05 -> 0.10		3,466,643	9,206,063	4.34	47.60	0.07
0.10 -> 0.15		1,068,846	2,837,378	1.34	47.87	0.12
0.15 -> 0.20		297,646	790,910	0.37	49.00	0.17
0.20 -> 0.25		91,661	243,643	0.11	49.73	0.22
Total		**90,902,403**	**212,162,405**	**99.97**	**-**	**-**
0.25 -> 0.30	PAF	18,069	47,953	0.02	49.21	0.27
0.30 -> 99.0		4,265	11,302	0.01	50.13	0.32
Total		**22,334**	**59,255**	**0.03**	**-**	**-**
Total		**90,924,737**	**212,221,661**	**100**	**-**	**-**

4.3 Conceptual Model

A conceptual model has been developed to account for the potential of overburden, waste rock and the ore body to produce acidity based on findings from the mineralogical and ABA assessments during the exploration and bulk sampling activities. The ultimate objective in the development of an interpretive AMD framework, is to provide a basis for the prediction of likely chemical processes that may develop during mining and post closure. The framework is to be tested by further sampling and analysis as detailed below. Thus, the conceptual model, which reasonably accounts for the conditions observed at the site, includes:

- Deposit C, due to its mineralogical characteristics and the low content of sulfide bearing materials, has a low likelihood of producing AMD. Equally, the risk of AMD produced by the materials removed during mining is low. An indicative rock-seepage assessment to verify this is required and was included in the supplementary program.
- Low sulfide concentrations (S%<0.25) in 2,510 samples and ABA assessment of 25 samples extracted from the bulk sampling area indicated that PAF materials are sporadic, highly localised and confined to about nine locations (bores). Four locations (bores) contain samples located beneath the DSO body (Figure 10).
- The majority (~85%) of PAF materials occur outside and/or beneath the base of the proposed open pit (Figures 8 and 10). However, if the pit is extended to between 30m and 40m below surface, a small portion of PAF materials, those confined to five locations (bores RR00046, RR00301, RR00435, RR00443 and RR00451), will have to be removed (Figure 10). The small extent and quantity do not require a comprehensive PAF management plan. Careful demarcation of the area, selective extraction and disposal by encapsulation in purpose designed and built cells during mining activities are recommended as first order management procedures.
- Ground water was encountered between 9m (across lower lying ground to the west of the open pit) and 65m (across higher lying ground and beneath the open pit) below surface. Whilst the top 10m is generally a sequence of regolith, alluvial and extremely weathered sandstones with interbedded siltstones, there is a distinct separation and confining layer, slightly weathered to unweathered siltstone with fine sandstone layers, between the shallow alluvial system and the deep fractured aquifer system. The main deep fractured aquifer comprises of a sequence of interlayered siltstones, weathered iron rich sandstones, arkosic sandstones, shales and localised mudstones in which ground water may be encountered between 20m and about 67m (beneath the open pit below surface. The larger quantities of ground water are encountered in the iron-rich, weathered sandstones at about 47m below surface. This aquifer is underlain by a thick sequence of siltstones

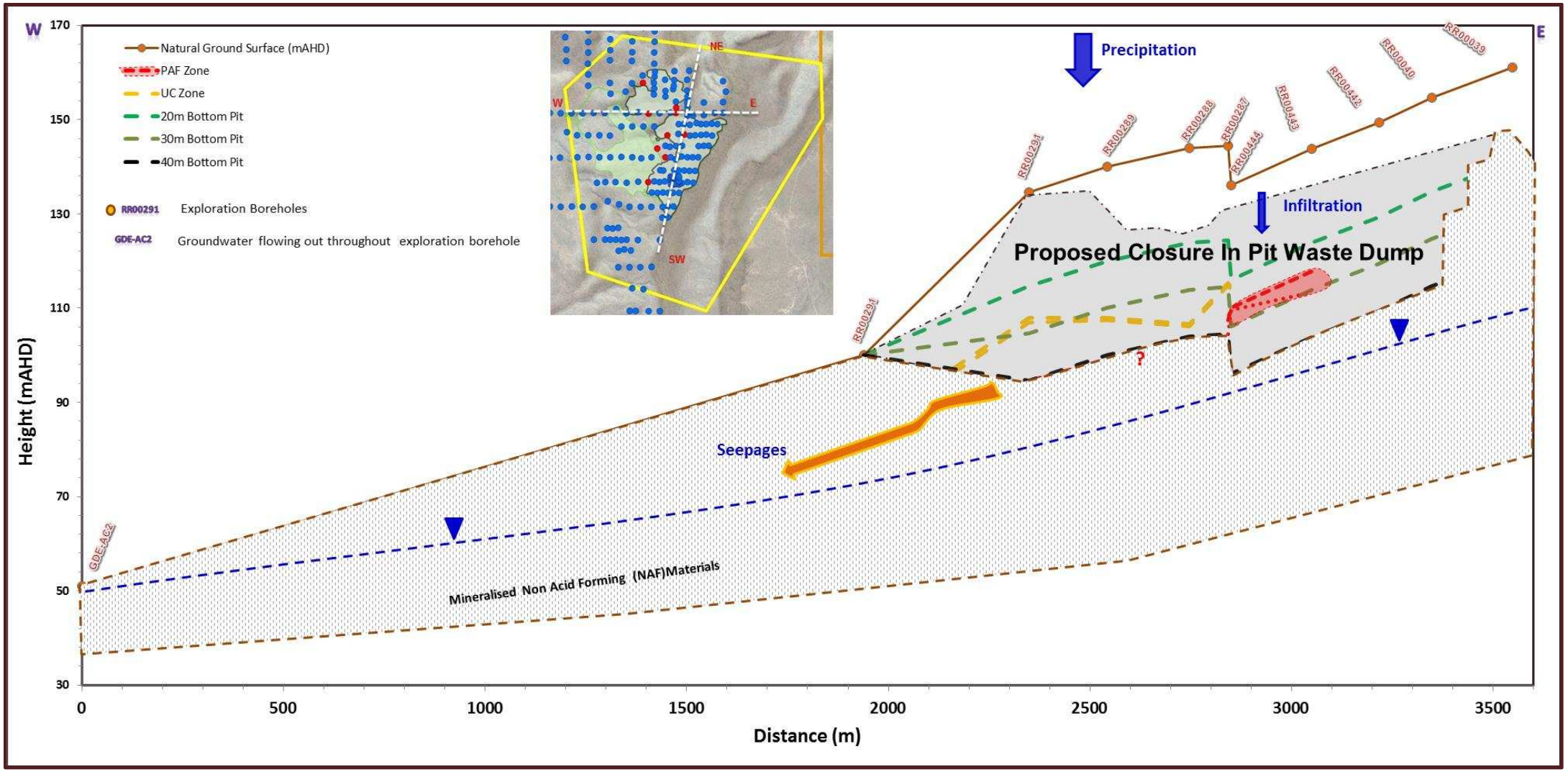

Figure 10: East-West Cross Section of the Northern Section of Deposit C.

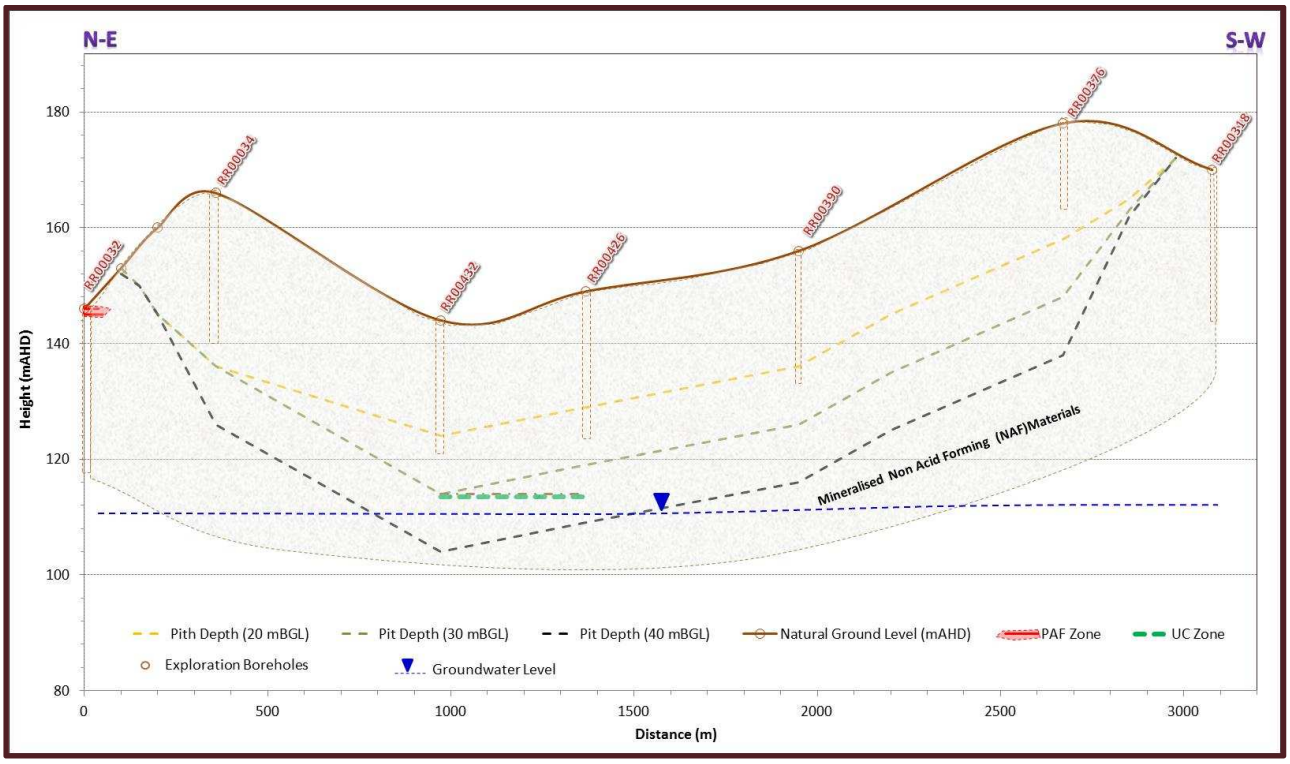

Figure 11: North-South Cross Section of Deposit C.

overlying very hard bluish dolerite.

- Groundwater levels at the eastern-south-eastern side of the open pit are deep but shallow, almost at the surface, in the west-north-west away from the open pit (Pendragon, 2013). The preferential ground water flow is westerly with the potential of these discharging into a sink system located to the west away from the open pit (Pendragon 2013).
- Ground water was not encountered, neither during exploratory drilling nor the subsequent drilling for the bulk sampling program, within the confines of the open pit. Mining is therefore unlikely to intersect ground water and consequently there will be no influx into the open pit (Pendragon, 2013).
- There is concern whether ground water will be impacted by infiltration of rain through the base of the open pit during mining and backfilling post closure (Figure 10). These potential seepages may migrate through natural undisturbed PAF bodies underlying the open pit. Infiltrating waters may transport oxygen into prevailing anoxic environments. However, PAF bodies are small and isolated and evaporation exceeds rainfall by several orders of magnitude which limit the quantity of water that may infiltrate through the base of the open pit. Rain falling into the open pit may also be diverted away from areas where PAF bodies are known to exist.
- Further targeted assessments i.e. to ascertain the areal extent of PAF materials, using mineralogical, ABA and hydrogeochemical studies are to be undertaken to verify these findings and for the EIS requirements to be met with integrity.

5. Supplementary AMD Investigation

5.1 Justification

Whilst the initial geochemical evaluation of overburden, waste rock and ore body materials indicated that the likelihood of AMD production within the footprint of the open pit is very low and would not represent an environmental constraint to mining, it was considered necessary to develop a supplementary program to confirm whether:

- The observations made in the conceptual model were appropriate and correct.
- Areas identified containing PAF materials are limited in areal extent and would not meaningfully impact mining and closure.
- Potential seepages (leachates) may impact surface and ground water quality.

5.2 Sample Selection, Collection and Field Description

5.2.1 Sample Selection and Collection

Samples of overburden, waste rock and ore materials were obtained from:

- 7 existing RC bores, and
- 21 new AC bores.

The AMD drilling program was completed in August 2013. Drilling targets were selected to investigate the lateral extent of PAF zones, identified during earlier assessments, in-ore-zones and below-ore-zones (Table 11 and Figure 12). Observations made during the development of the conceptual model aided to focus in-ore-zones as these may pose a greater impact and risk during mining.

Table 11: Sample Descriptions.

AMD Sampling	Hole No	Coordinates		Depth (mBGL)		Lithotype	DSO	Colour
		Eastern	Northern	From	To			
RC Bore Samples								
RR27675	RR0043D	427798	8371000	3	4	Qst/Slt	In	Grey/Brown
RR27676	RR0044D	427603	8371001	6	7	Fst/Clay	In	Brown/Grey
RR27674	RR0042D	427600	8371800	9	10	Fst/Sst	In	Purple/Brown
RR27672	RR0034D	427600	8372200	11	12	Sst	In	Grey
RR27673	RR0037D	428250	8372000	22	23	Slt	In	Brown
RR27678	RR0049D	426949	8370099	25	26	Slt	Below	Brown
RR27677	RR0046D	427200	8370995	37	38	Slt	In	Grey
AC Bore Samples								
27/06/2013	AMDAC- 17	427413	8370497	8	9	Irs	in	Red
26/06/2013	AMDAC-25	427599	8371756	9	10	Fst	in	Red
27/06/2013	AMDAC- 16	427299	8370575	10	11	Fst	in	Red
26/06/2013	AMDAC- 02	428178	8371800	16	17	Fst	in	Red
27/07/2013	AMDAC- 09	426399	8371556	20	21	Xcly	in	Cream/white
23/06/2013	AMDAC- 15	427172	8370350	21	22	Fsl	in	Red
26/06/2013	AMDAC-24	428248	8372001	22	23	Sst	in	Light grey
24/06/2013	AMDAC- 12	427668	8370547	24	25	Qzt	Below	Grey

AMD Sampling	Hole No	Coordinates		Depth (mBGL)		Lithotype	DSO	Colour
		Eastern	Northern	From	To			
24/06/2013	AMDAC- 07	427200	8370096	25	26	Fst	Below	Red
26/06/2013	AMDAC- 22	427426	8371898	26	27	Dol	Below	Light grey
23/06/2013	AMDAC- 13	427114	8370535	27	28	Fst	in	Red
26/06/2013	AMDAC-26	417152	8372104	30	30.5	Irs	in	Red
26/06/2013	AMDAC- 10	428004	8371416	31	32	Irs	in	Red/Purple
22/06/2013	AMDAC- 11	427108	8371126	33	34	Irs	in	Red/Purple
23/06/2013	AMDAC- 14	426977	8370582	35	36	Slt	Below	Cream
25/06/2013	AMDAC- 20	427530	8371472	34	36	Irs	in	Red
25/06/2013	AMDAC- 19	427275	8371359	36	37	Irs	in	Red
27/06/2013	AMDAC- 21	427430	8371820	36	37	Dol	in	Light grey
27/06/2013	AMDAC- 08	427004	8371788	38	39	Shl	in	Light grey
24/06/2013	AMDAC- 18	427258	8371169	38	39	Sst	in	Yellow
26/06/2013	AMDAC- 23	427004	8372465	41	43	Dol	in	Light grey

Notes: Sst denotes sandstone; **Slt** siltstone, **Fst** ferruginous sandstone; **Qst** quartz sandstone; **Qzt** quartzite; **Irs** ironstone sparse oolites; **Fsl** ferruginous siltstone; **Dol** dolerite; **Shl** shale and **Xclay** for undifferentiated clay.

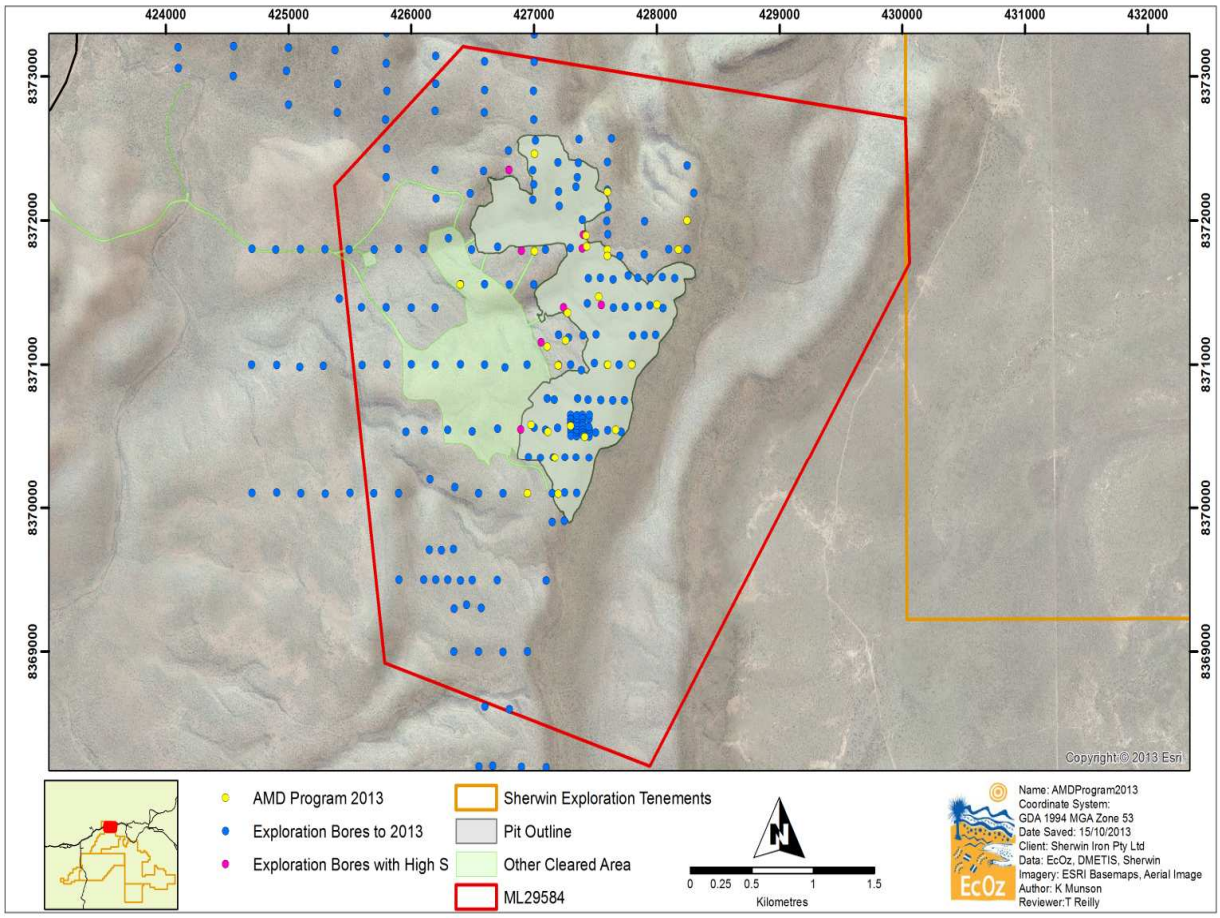

Figure 12: Location of AMD Samples 2013 Drilling Program.

5.2.2 Sample Field Description

Lithological descriptions, weathering degree, colour and presence of sulfide minerals of the samples appear in Table 11. The overall lithological description indicates that the samples from the in-, above- and below-ore-zones (Section 2.1.3 and Figures 5 and 6) are substantially similar and express continuous lithological sequences with depth.

Although a sequence of claystone, sandstone, quartz sandstone, shale and siltstone is dominant across the area, a number of samples were collected from the upper, middle and lower ironstone sparse oolite sequences. Some samples targeted the ferruginous sandstones layers which were observed to host the disseminated but scarce pyrite (refer Table 7). This sequence is normally located at intermediate depths ranging from 10m to about 30m below ground level. Shales, siltstones and ferruginous siltstones are underlying these sequences and locally overly doleritic intrusions (Figures 5 and 6).

Near surface sequences are typically highly to extremely weathered sandstones, siltstones and clays. Outcrops of the upper ironstone sparse oolites are also frequent and normally underly thin top soils and clays.

Because the major lithological sequences are similar and continuous with depth, the findings of the investigations are discussed as a whole.

5.3 Mineralogical Assessment

5.3.1 XRD Analysis

Twenty-one samples from the AC bores were submitted for quantitative powder X-ray diffraction (XRD) phase analysis of their crystalline and amorphous contents (refer Tables 11 and 12 and Appendix B). The samples were crushed and milled to <75µm. Sample aliquots were then taken and micronized. Duplicate samples AMDAC02s, AMDAC10s and AMDAC25s were also prepared.

The XRD patterns were analysed using the Bruker Diffrac.EVA 3.0 Search/Match software with the ICDD PDF-2 (2011) database and the quantitative phase analysis was performed using SIROQUANTTM Version 3 software (Appendix B).

Mineralogical XRD results appear in Table 12 below. The samples contain key fingerprint minerals of the deposit including iron silicate minerals with subsequent iron oxides such as hematite and goethite. These later minerals, particularly hematite, are dominant in the ironstone sparse oolite (sample AMDAC10) and in the ferruginous sandstones (sample AMDAC 13). The highest concentrations of magnetite are related to the siltstones.

Clay minerals including kaolin, muscovite, illite and chlorite are significant and higher proportions of these are found in the sandstones and siltstones. Kaolin tends to be dominant in all samples, with the exception of the deep bedded AMDAC23 sample (dolerite), in which illite/muscovite and chlorite are significant components (Table 12). Dolerites are also particularly richer in amorphous minerals. No sulfide minerals were reported to be significant in any of the assessed samples. Siderites ($FeCO_3$) are significant in the ironstone sparse oolite, shales and dolerites (Table 12). Siderites are known to interfere in the determination of the neutralisation potential of the samples (Haney *et al.* 2006) and therefore recorded acid neutralisation capacities (ANC) are often biased on the high-side of the buffering capacities of the samples.

5.3.2 XRD and XRF Analyses

Samples from five of the RC bores were analysed for their mineralogical and chemical composition. Assessments included XRD and XRF analysis. The findings are summarised in Table 13; detailed appraisals are included in Appendix C.

Table 12: XRD Analyses.

				Phases													
Sample ID		**Unit**	**Field Descriptor**	**Amorphous content**	**11Å Expanding clay**	**14Å Expanding clay**	**Chlorite**	**Clinochlore**	**Clinochlore / Serpentine**	**Gibbsite**	**Goethite**	**Hematite**	**Illite / Muscovite**	**Kaolin**	**Magnetite / Maghemite**	**Quartz**	**Siderite**	**Zeolite**
AMDAC02s	**Original**	**wt%**	Fst	3							12	9	2	16		58		
	Duplicate	**wt%**		4							11	9	3	17		57		
AMDAC07s		**wt%**	Fst	3						1	4	11	4	18		59		
AMDAC08s		**wt%**	Shl	2								32	1	6		23	37	
AMDAC09s		**wt%**	Xcly	8							18	30		0		43		1
AMDAC10s	**Original**	**wt%**	Irs	3							6	79			6	6		
	Duplicate	**wt%**		2							6	80			6	6		
AMDAC11s		**wt%**	Irs	32					9		<1	12	6	1	5	26	10	
AMDAC12s		**wt%**	Qzt	12								7	21	12	<1	49		
AMDAC13s		**wt%**	Fst	1							1	72		5	2	19		
AMDAC14s		**wt%**	Slt	9				8				4	17	12	50			
AMDAC15s		**wt%**	Fsl	14							1	11	2	17		55		
AMDAC16s		**wt%**	Fst	9							27	40		7	8	10		
AMDAC17s		**wt%**	Irs	9							20	34	3	6	5	22		
AMDAC18s		**wt%**	Sst	10		2					2	55	4		5	23		
AMDAC19s		**wt%**	Irs	8							1	62		5	9	8	8	
AMDAC20s		**wt%**	Irs	22	13							19		1	8	31	6	
AMDAC21s		**wt%**	Dol	16		4					<1	5	1	16		55	3	
AMDAC22s		**wt%**	Dol	26		<1					1	2	<1	10	3	43	14	
AMDAC23s		**wt%**	Dol	8			11						20			61		
AMDAC24s		**wt%**		7							10	8	1	10		65		
AMDAC25s	**Original**	**wt%**	Fst	13							26	10	<1	15		36		
	Duplicate	**wt%**		11							27	11	1	15		36		
AMDAC26s		**wt%**	Irs	5							16	2	1	17		59		
Average				**10**	**13**	**3**	**11**	**8**	**9**	**1**	**11**	**26**	**6**	**10**	**10**	**37**	**13**	**1**
Maximum				**32**	**13**	**4**	**11**	**8**	**9**	**1**	**27**	**80**	**21**	**18**	**50**	**65**	**37**	**1**
Minimum				**1**	**13**	**2**	**11**	**8**	**9**	**1**	**1**	**2**	**1**	**0**	**2**	**6**	**3**	**1**

Table 13: XRD and XRF Assessment.

Sample ID	XRD Assessment		Lithology	XRF Assessment
	Mineral Phase	Concentration (%)		Composition
RR0034D			Sandstone	Major quantities of particles containing primarily oxygen and silicon with minor concentrations of iron, aluminium, and manganese (possible quartz). Major quantities of particles containing primarily oxygen and iron with minor concentrations of silicon, aluminium, **sulfur**, titanium and manganese (possible iron oxide).
RR0037D	Quartz, syn (SiO_2)	61	Siltstone	Major quantities of particle containing primarily silicon and oxygen with varying minor quantities of iron, aluminium, potassium, titanium, calcium, lanthanum, cerium, neodynium and **sulfur** (possible quartz). Minor quantities of particles containing primarily of iron and oxygen with minor quantities of aluminium, silicon, potassium and titanium (possible iron oxide). Minor quantities of particles containing primarily of silicon, aluminium and oxygen with minor quantities of potassium and iron (possible kaolinite). Trace quantities of particles containing lanthanum, cerium, neodynium and **sulfur**.
	Kaolinite-1Ad ($Al_2Si_2O_5(OH)_4$)	22		
	Muscovite-2M1 ($KAl_2(Si, Al)_4 O_{10} (OH)_2$)	16		
	Hematite, syn (Fe_2O_3)	1		
RR0043D	Quartz (SiO_2)	84	Quartz Sandstone and Siltstone	Major quantities of particle containing primarily of silicon and oxygen with minor quantities of aluminium, iron, potassium, **sulfur**, sodium, magnesium and titanium (possible quartz). Trace quantities of particles containing primarily of iron and oxygen with minor quantities of silicon and aluminium (possible iron oxide).
	Kaolinite-1A ($Al_2 Si_2 O_5(OH)_4$)	8		
	Goethite, aluminian, syn ($Fe_{0.93} Al_{0.07} O(OH)$)	5		
	Muscovite-2M1 ($K_{0.8}Na_{0.2}Fe_{0.05} Al_{2.95} Si_{3.1}O_{10}(OH)_2$)	3		
RR0044D	Quartz (SiO_2)	73	Ferruginous sandstone	Major quantities of particles containing primarily silicon and oxygen and minor quantities of aluminium, iron, magnesium, potassium, manganese, **sulfur**, phosphorus, calcium (possible quartz). Trace quantities of particles containing lanthanum, cerium, titanium and neodymium, possibly associated with phosphorous.
	Clinochlore-1MIIb, ferroan ($(Mg, Fe)_6 (Si, Al)_4 O_{10} (OH)_8$)	22		
	Muscovite-2M1 ($KAl_2 (Si, Al)_4 O_{10}(OH)_2$)	3		
	Margarite-2M1 ($Na_{0.2}Ca_{0.8}Al_{3.9} Si_{2.1}O_{11}(OH)$)	2		
RR0049D	Quartz (SiO_2)	66	Siltstone	
	Kaolinite-1A ($Al_2 Si_2O_5(OH)_4$)	27		
	Muscovite-2M1 ($KAl_2(Si, Al)_4O_{10} (OH)_2$)	3		
	Goethite ($Fe_2O_3 \cdot H_2O$)	3		
	Hematite, syn (Fe_2O_3)	1		

The samples from the RC bores are composed of iron-silicate minerals. Clay minerals such as muscovite and kaolinites are also relevant with the highest concentrations in the sand and siltstones. Besides substantial concentrations of silicon and oxygen, samples are chemically dominated by iron, aluminium and potassium. Magnesium, manganese, phosphorous and sulfur are also present but in trace quantities. The highest concentration of sulfur occurs in sample RR0037D (siltstone). Similar to sodium, cerium and titanium, calcium is also sporadic and occurs in the ferruginous sandstone and siltstones.

5.4 ABA Assessment

All samples were assessed for their acid and neutralising capacities (refer Section 3.1.2). The ABA and NAG characteristics (Table 13 and Appendix D) of the samples indicate that:

- Paste pH ranges from 5.4 to 8.0 with an average circumneutral pH of 6.4 indicating weathering of waste rocks will preferentially release neutral solutions. Paste electrical conductivity ranges from

8µS/cm to 105µS/cm with an average of 39µS/cm. The highest EC pertains to the siltstone sample RR0046D.

- On their sulfide concentration, which ranges from 0.001% to 0.37% with an average value of 0.04%, only the AMDAC21 dolerite sample can be classified as PAF. This sample was extracted from a site near bores RR00444 and RR00443 implying that the lateral extent of PAF materials is reduced to the dolerite.
- The APR method is generally the most conservative quantifier for potential acid producers. The AMDAC21, the RR0037D (siltstone), RR0044D (ferruginous sandstone with clay) and RR049D (siltstone) samples have APRs <1.0.

  Low APR's normally reflect low buffering capacity of the samples and thus low capacity to neutralise the acid produced by a given sample. However in natural conditions, as many investigators suggests (e.g. Lapakko, 1982), the lag-time between producing acidity and its consumption may not replicate those attained during laboratory testing and thus the samples will require further evaluation.
- When samples are assessed on their NAG characteristics, the AMDAC21 (dolerite) sample recorded a low NAG pH of 3.8 and a NAG (pH 7) of 11kgH_2SO_4/t. However the paste pH of the sample is circumneutral indicating the ground mass of the sample is relatively reactive in the high-ANC-side and have the potential to consume acidity produced in the short-term. Amorphous minerals which can include oxides, silicate and phosphates are relatively high (26%) in the sample. Carbon concentration (1.71%) is also relatively high, second to the highest of 4.21% in the shales. High carbon in shales may be indicative of the high siderite concentrations in the sample.
- When samples are compared between their NAG and APR characteristics (Figure 13), only sample AMDAC21 falls within the PAF domain. The three other samples, RR0037D, RR0044D and RR049D fall within the zone of uncertainty.
- A large number of samples comprising ferruginous sandstones, sandstones, shales and quartzite have high APRs (>10) indicating these samples have elevated potentials to neutralize acid.

Based on the above descriptions, the deep AMDAC21 dolerite is the only one sample that can be classified by both the ABA and NAG approaches as PAF materials. The remaining samples can be classified as having uncertain (3 samples) or NAF (24 samples) characteristics.

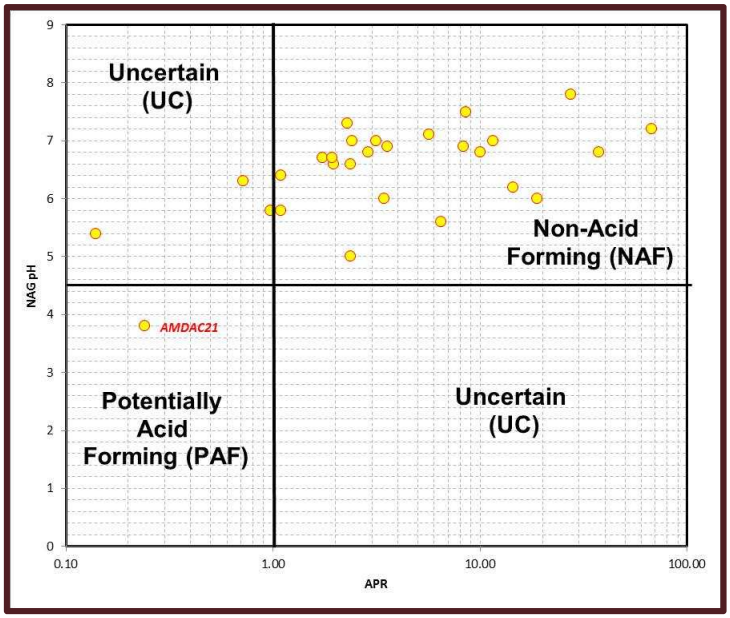

Figure 13: APR (ABA parameter) and NAG pH.

Table 14: ABA/NAG Assessment.

Sample ID	Lithology	Fizz Rating	Moisture Content	pH Value	Electrical Conductivity	pH (OX)	NAG (pH 4.5)	NAG (pH 7.0)	Final pH	ANC as H_2SO_4	C	ANC as $CaCO_3$	Total Soluble Salts	Sulfate as SO_4^{2-}		Sulfur - Total as S (LECO)	Sulfide as S	MPA	NAPP	APR	ABA Classification			
		Fizz Unit	%	pH Unit	µS/cm	pH Unit	kg H_2SO_4/t		pH Unit	kg H_2SO_4 equiv./t	%	% $CaCO_3$	mg/kg	mg/kg	%	%		kg H_2SO_4 equiv./t			Based on Sulfide as S	Based on NAG	Based on APR	General ABA/NAG Classification
RR0034D	Sst	0	<1.0	6.20	48.0	6.6	<0.1	0.3	8.0	0.5	0.001	0.10	60	100	0.003	0.01	0.01	0.21	-0.29	2.37	NAF	NAF	NAF	NAF
RR0037D	Slt	0	<1.0	6.10	55.0	5.4	<0.1	8.9	8.6	0.5	0.001	0.10	67	100	0.003	0.12	0.12	3.58	3.08	0.14	NAF	NAF	PAF	UC
RR0042D	Fst/Sst	0	<1.0	6.10	100.0	6.4	<0.1	0.4		1.0	0.001	0.10	127	640	0.020	0.05	0.03	0.92	-0.08	1.09	NAF	NAF	NAF	NAF
RR0043D	Qst/Slt	0	<1.0	6.00	33.0	5.8	<0.1	7.4	8.9	0.9	0.001	0.10	39	100	0.003	0.03	0.03	0.82	-0.08	1.09	NAF	NAF	NAF	NAF
RR0044D	Fst/Clay	0	<1.0	6.30	57.0	5.8	<0.1	4.4		0.5	0.001	0.10	58	100	0.003	0.02	0.02	0.52	0.02	0.97	NAF	NAF	PAF	UC
RR0046D	Slt	1	<1.0	7.60	105.0	7.5	<0.1	<0.1	7.4	9.6	0.012	1.00	113	100	0.003	0.04	0.04	1.13	-8.47	8.51	NAF	NAF	NAF	NAF
RR0049D	Slt	0	<1.0	5.70	39.0	6.3	<0.1	0.2		0.5	0.001	0.10	56	230	0.007	0.03	0.02	0.70	0.20	0.72	NAF	NAF	PAF	UC
AMDAC02	Fst			6.30	13.0	6.0		3.44		0.84	0.05	4.17					0.01	0.24	-0.60	3.43	NAF	NAF	NAF	NAF
AMDAC07	Fst			6.20	18.0	6.9		<0.01		2.04	0.04	3.33					0.01	0.24	-1.80	8.33	NAF	NAF	NAF	NAF
AMDAC08	Shl			7.80	81.0	7.8		<0.01		43.4	4.21	350.7					0.05	1.59	-41.8	27.28	NAF	NAF	NAF	NAF
AMDAC09	Xcly			5.70	26.0	7.0		<0.01		2.51	0.05	4.17					0.03	0.80	-1.71	3.15	NAF	NAF	NAF	NAF
AMDAC10	Irs			5.50	17.0	6.7		0.39		0.85	0.03	2.50					0.02	0.49	-0.36	1.74	NAF	NAF	NAF	NAF
AMDAC11	Irs			6.90	51.0	6.9		0.24		4.57	1.10	91.6					0.04	1.29	-3.28	3.56	NAF	NAF	NAF	NAF
AMDAC12	Qzt			7.00	21.0	6.2		5.65		1.77	0.03	2.50					0.004	0.12	-1.65	14.46	NAF	NAF	NAF	NAF
AMDAC13	Fst			5.90	12.0	6.8		0.24		2.29	0.03	2.50					0.002	0.06	-2.23	37.42	NAF	NAF	NAF	NAF
AMDAC14	Slt			8.00	40.0	6.6		0.48		2.89	0.36	29.99					0.05	1.47	-1.42	1.97	NAF	NAF	NAF	NAF
AMDAC15	Fsl			6.40	13.0	7.0		<0.01		2.12	0.06	5.00					0.01	0.18	-1.94	11.55	NAF	NAF	NAF	NAF
AMDAC16	Fst			5.70	11.0	7.0		<0.01		1.48	0.05	4.17					0.02	0.61	-0.87	2.42	NAF	NAF	NAF	NAF
AMDAC17	Irs			5.60	19.0	7.3		<0.01		1.26	0.05	4.17					0.02	0.55	-0.71	2.29	NAF	NAF	NAF	NAF

Sample ID	Lithology	Fizz Rating	Moisture Content	pH Value	Electrical Conductivity	pH (OX)	NAG (pH 4.5)	NAG (pH 7.0)	Final pH	ANC as H_2SO_4	C	ANC as $CaCO_3$	Total Soluble Salts	Sulfate as SO_4 $^{2-}$		Sulfur - Total as S (LECO)	Sulfide as S	MPA	NAPP	APR	ABA Classification			
		Fizz Unit	%	pH Unit	µS/cm	pH Unit	kg H_2SO_4/t		pH Unit	kg H_2SO_4 equiv./t	%	% $CaCO_3$	mg/kg	mg/kg	%	%		kg H_2SO_4 equiv./t			Based on Sulfide as S	Based on NAG	Based on APR	General ABA/NAG Classification
AMDAC18	Sst			7.00	24.0	7.2		<0.01		4.13	0.11	9.16					0.002	0.06	-4.07	67.48	NAF	NAF	NAF	NAF
AMDAC19	Irs			7.00	46.0	7.1		<0.01		6.24	0.70	58.31					0.04	1.10	-5.14	5.66	NAF	NAF	NAF	NAF
AMDAC20	Irs			7.20	58.0	6.8		0.24		9.48	1.04	86.63					0.11	3.30	-6.18	2.87	NAF	NAF	NAF	NAF
AMDAC21	Dol			6.50	58.0	3.8		11.7		2.7	0.54	44.98					0.37	11.26	8.56	0.24	PAF	PAF	PAF	PAF
AMDAC22	Dol			6.90	65.0	6.8		0.34		38.5	1.72	143.28					0.13	3.86	-34.64	9.99	NAF	NAF	NAF	NAF
AMDAC23	Dol			7.20	27.0	5.0		6.56		2.61	0.52	43.32					0.04	1.10	-1.51	2.37	NAF	NAF	NAF	NAF
AMDAC24	SSt			5.40	22.0	6.7		0.34		1.42	0.04	3.33					0.02	0.73	-0.69	1.93	NAF	NAF	NAF	NAF
AMDAC25	Fst			6.00	8.0	6.0		4.89		3.46	0.05	4.17					0.01	0.18	-3.28	18.85	NAF	NAF	NAF	NAF
AMDAC26	Lrs			5.50	22.0	5.6		6.52		3.16	0.05	4.17					0.02	0.49	-2.67	6.45	NAF	NAF	NAF	NAF
Average				**6.42**	**38.89**	**6.5**	**<0.1**	**3.30**	**8.2**	**5.40**	**0.39**	**32.28**	**74.29**	**196**	**0.01**	**0.04**	**0.04**	**1.34**	**-4.06**	**8.87**				
Maximum				**8.00**	**105.0**	**7.8**	**<0.1**	**11.70**	**8.9**	**43.40**	**4.21**	**350.69**	**127.00**	**640**	**0.02**	**0.12**	**0.37**	**11.26**	**8.56**	**67.48**				
Minimum				**5.40**	**8.00**	**3.8**	**<0.1**	**0.20**	**7.4**	**0.50**	**0.00**	**0.10**	**39.00**	**100**	**0.00**	**0.01**	**0.001**	**0.06**	**-41.81**	**0.14**				

Notes: Sst denotes sandstone; **Slt** siltstone, **Fst** ferruginous sandstone; **Qst** quartz sandstone; **Qzt** quartzite; **Irs** ironstone sparse oolites; **Fsl** ferruginous siltstone; **Dol** dolerite; **Shl** shale and **Xclay** undifferentiated clay. **PAF** (Potentially Acid Forming materials); **NAF** (Non Acid Forming Materials); **UC** (Uncertain to be defined as NAF or PAF).

5.5 Hydrogeochemical Evaluation

The quantity and mobility of solutes in disturbed materials are dependent on changes to environmental, geological, geochemical and physical characteristics of the parent materials. The hydrogeochemical processes developing as a result of the mining operation thus control the chemical evolution of surface and ground waters, pore waters within waste rock dumps (WRD) and potentially the pore water in the vegetation rooting zones. The assessment of solute quantity and quality entails preparing and analysing leachates from selected drill chip and core samples in the laboratory.

Leachates were predominantly circumneutral (pH 6.5) with pH ranging between 5.4 and 7.8 (Table 15 and Appendix D). The highest pH (7.8) occurs in the deep shales, whilst the lowest occurs in the ironstone sparse oolites and ferricrete sandstones located between the surface and 25m depth (Figure 14). With increasing depth EC normally follows a pattern of when pH is low EC is high and *vice versa* (Figure 14).

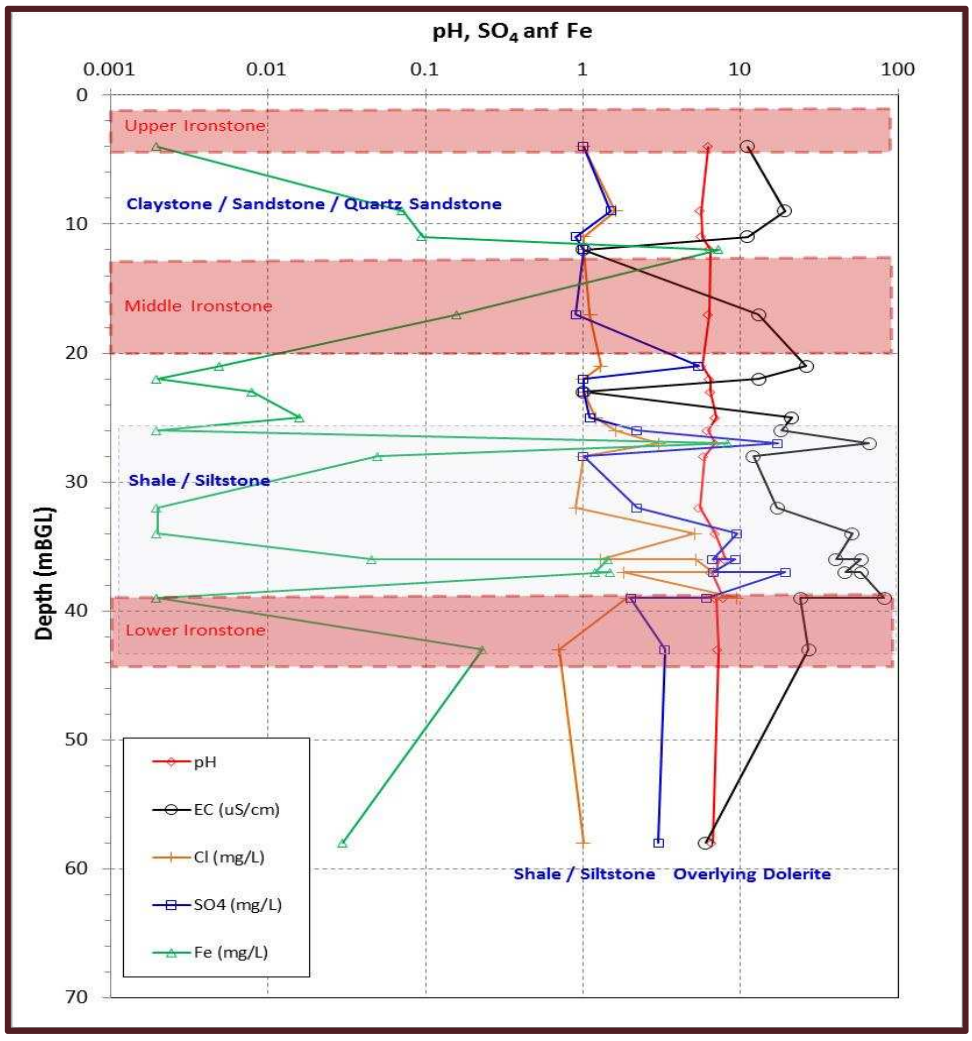

Figure 14: Analyte Concentrations with Depth.

Key anions including sulphate (SO_4) and chloride (Cl) were also assessed on their distribution with depth to distinguish any potential zones with enrichment (Figure 14). The highest concentrations of both can be seen among shales and siltstones at depths between 25m and 42m (Figure 14) and these correlate with slight decreases in pHs. The electrical conductivity of the samples also increases to about 40m depth indicating higher activity and availability of mobile solutes that may be resulting from increasing iron concentrations and seasonal ground water fluctuations.

Table 15: Chemical Composition of Laboratory Leachates.

	Lithology	Depth	pH Value	Electrical Conductivity	Total Dissolved Solids	Acidity as $CaCO_3$	Total Alkalinity as $CaCO_3$	Bicarbonate Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Hydroxide Alkalinity as $CaCO_3$	Chloride	Sulfate as SO_4	Calcium	Potassium	Magnesium	Sodium	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Manganese	Nickel	Lead	Uranium	Zinc
Units		m	units	µS/cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Drill Chips																											
AMDAC02S	Fst	17	6.3	13	90		1	1	<1	<1	1.1	0.9	<0.1	0.6	<0.1	1.6	0.9	0.1	<0.02	<0.1	0.04	<2	1.38	<0.01	0.02	<0.001	<0.1
AMDAC07S	Fst	26	6.2	18	110		1	1	<1	<1	1.6	2.2	<0.1	1.6	<0.1	1.8	0.9	0.1	<0.02	<0.1	0.05	2	39.1	0.26	<0.01	0.001	<0.1
AMDAC08S	Shl	39	7.8	81	110		38	38	<1	<1	9.5	6.1	0.5	1.5	7.4	2.4	58.2	7	<0.02	<0.1	0.1	1050	45.5	0.09	0.02	0.01	<0.1
AMDAC09S	Xcly	21	5.7	26	130		<1	<1	<1	<1	1.3	5.4	0.1	0.6	0.6	1.3	1.7	0.2	<0.02	<0.1	0.03	<2	1330	2.16	<0.01	0.004	0.3
AMDAC10S	Irs	32	5.5	17	<10		<1	<1	<1	<1	0.9	2.2	<0.1	0.7	0.1	1.5	1	<0.05	<0.02	<0.1	0.02	<2	126	0.23	<0.01	<0.001	0.4
AMDAC11S	Irs	34	6.9	51	170		9	9	<1	<1	5.1	9.5	<0.1	1.1	3.7	1.9	91.5	1.6	<0.02	<0.1	0.04	1200	36	0.11	0.01	0.004	0.4
AMDAC12S	Qzt	25	7	21	100		11	11	<1	<1	1.2	1.1	<0.1	2	<0.1	1.6	106	0.15	<0.02	0.1	0.1	46	0.79	0.04	0.02	0.004	3.3
AMDAC13S	Fst	28	5.9	12	140		1	1	<1	<1	1	1	<0.1	0.5	<0.1	1.4	1.5	0.1	<0.02	<0.1	0.03	72	5.81	<0.01	<0.01	<0.001	<0.1
AMDAC14S	Slt	36	8	40	180		42	42	<1	<1	1.3	6.6	<0.1	7.6	0.2	1.7	1860	10.5	<0.02	1	0.12	1450	24	0.3	0.18	0.138	0.6
AMDAC15S	Fsl	22	6.4	13	110		2	2	<1	<1	1	1	<0.1	1.4	<0.1	1	3.4	0.1	<0.02	<0.1	0.02	16	1.66	<0.01	<0.01	0.003	<0.1
AMDAC16S	Fst	11	5.7	11	180		1	1	<1	<1	1	0.9	<0.1	0.6	<0.1	1	1.3	<0.05	<0.02	<0.1	<0.01	<2	27.4	0.14	<0.01	<0.001	0.6
AMDAC17S	Irs	9	5.6	19	108		<1	<1	<1	<1	1.6	1.5	<0.1	1	0.2	1.7	2	0.05	<0.02	<0.1	0.02	<2	157	0.63	<0.01	0.003	<0.1
AMDAC18S	Sst	39	7	24	280		13	13	<1	<1	1.9	2	<0.1	0.6	0.5	2.5	98.3	2.1	<0.02	0.1	0.25	2950	29.9	0.08	0.03	0.015	2.7
AMDAC19S	Irs	37	7	46	330		10	10	<1	<1	6.7	6.7	<0.1	0.7	3.4	1.5	101	2.9	<0.02	0.1	0.51	8350	27.5	0.12	0.06	0.013	1.2
AMDAC20S	Irs	36	7.2	58	140		23	23	<1	<1	5.2	9.2	<0.1	1.8	2.6	4.7	94.5	3.35	<0.02	<0.1	0.16	1500	24.1	0.22	0.01	0.023	1.1
AMDAC21S	Dol	37	6.5	58	150		2	2	<1	<1	1.8	19.1	0.1	1.1	4.6	1.2	68.8	1.2	<0.02	<0.1	<0.01	230	19.7	0.15	0.02	0.005	<0.1
AMDAC22S	Dol	27	6.9	65	40		4	4	<1	<1	3	17.1	0.2	0.7	5.4	1.2	24.2	1.65	<0.02	<0.1	<0.01	96	135	0.3	0.01	<0.001	<0.1
AMDAC23S	Dol	43	7.2	27	140		20	20	<1	<1	0.7	3.3	<0.1	3.9	<0.1	1.2	702	5.7	<0.02	0.5	0.04	298	2.79	0.12	0.06	0.085	2.4
AMDAC24S	Irs	23	5.4	22	20		<1	<1	<1	<1	1.4	3.6	<0.1	1.3	<0.1	1.6	3.7	0.1	<0.02	<0.1	0.11	8	362	4.93	<0.01	0.002	2.5
AMDAC25S	Sst	10	6	8	100		1	1	<1	<1	0.5	0.3	<0.1	0.7	<0.1	0.5	1.2	0.05	<0.02	<0.1	<0.01	<2	0.24	<0.01	<0.01	<0.001	0.6
AMDAC26S	Lrs	30.5	5.5	22	130		<1	<1	<1	<1	3	2.1	<0.1	0.8	<0.1	2.6	1.2	0.1	<0.02	<0.1	0.07	30	7.98	0.84	<0.01	<0.001	0.1
RC Cores																											
RR0034D	SSt	12	6.39	<1	<10	<1	<1	<1	<1	<1	1	1	<1	<1	<1	2	20	2	<0.01	<0.01	<0.01	<2	<0.01	<0.01	<0.01	<0.01	9
RR0037D	Slt	23	6.46	<1	12	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	2	50	7	<0.01	<0.01	<0.01	50	<0.01	<0.01	<0.01	<0.01	21
RR0043D	Qst/Slt	4	6.27	11	<10	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	2	90	1	<0.01	<0.01	<0.01	160	2	<0.01	<0.01	<0.01	21
RR0046D	Slt	58	6.61	6	13	<1	<1	<1	<1	<1	<1	3	<1	1	1	3	2720	4	<0.01	2	1	7300	113	<0.01	<0.01	<0.01	31
Average			6.46	29.09	126.50	<1	11.19	11.19	<1	#DIV/0!	2.24	4.60	0.23	1.45	2.48	1.80	244.13	2.22	<0.0001	0.63	0.15	1378.22	109.52	0.63	0.04	0.02	5.78
Maximum			8.00	81.00	330.00	<1	42.00	42.00	0.00	0.00	9.50	19.10	0.50	7.60	7.40	4.70	2720.00	10.50	<0.0001	2.00	1.00	8350.00	1330.00	4.93	0.18	0.14	31.00
Minimum			5.40	6.00	12.00	<1	1.00	1.00	0.00	0.00	0.50	0.30	0.10	0.50	0.10	0.50	0.90	0.05	<0.0001	0.10	0.02	2.00	0.24	0.04	0.01	0.00	0.10

Major ions are in the order of magnesium>sodium>potassium>calcium which would indicate substantial activity of dolerite and iron silicate components. Trace metals are in the order of Fe>Al>Mn with no significant concentrations of toxic elements such as cadmium and chromium. Although most of the samples are enriched in arsenic (refer Section 4.1.3), mobility of this element is very low with an average value of 2.22µg/L. Responding to increasing weathering near the surface and intermediate domains, iron activity tends to be higher with a slight decrease with depth (Figure 16).

A hydrogeochemical assessment of the leachates indicates that all leachates are very soft. Hardness of leachates is calculated in relation to calcium and magnesium concentrations and lower balances indicate low calcium and magnesium activity (Table 15). The shale and dolerite samples present higher magnesium concentrations as compared to calcium (Table 14) and this would indicate that their hardness is caused by magnesium. These samples, in addition to the ironstone sparse oolites, may produce HCO_3, Cl + SO_4 type leachates. Siltstones, ferruginous sandstones/siltstones and sandstones will likely produce Na + K type of leachates (Figure 15).

Table 16: Leachate Hardness.

Lithology	Total Hardness (mg/L $CaCO_3$)	Classification	Hardness Scale
FST	0.66	Very Soft	<50 Very Soft 50 – 100 Moderately Soft 100 – 150 Slightly Hard 150 – 200 Moderately Hard 200 – 300 Hard >300 Very Hard
Irs	8.48	Very Soft	
Sst	6.61	Very Soft	
Dol	20.96	Very Soft	
Slt	4.97	Very Soft	
Lrs	0.66	Very Soft	
Shl	31.71	Very Soft	
Qzt	0.66	Very Soft	
Xcly	2.72	Very Soft	

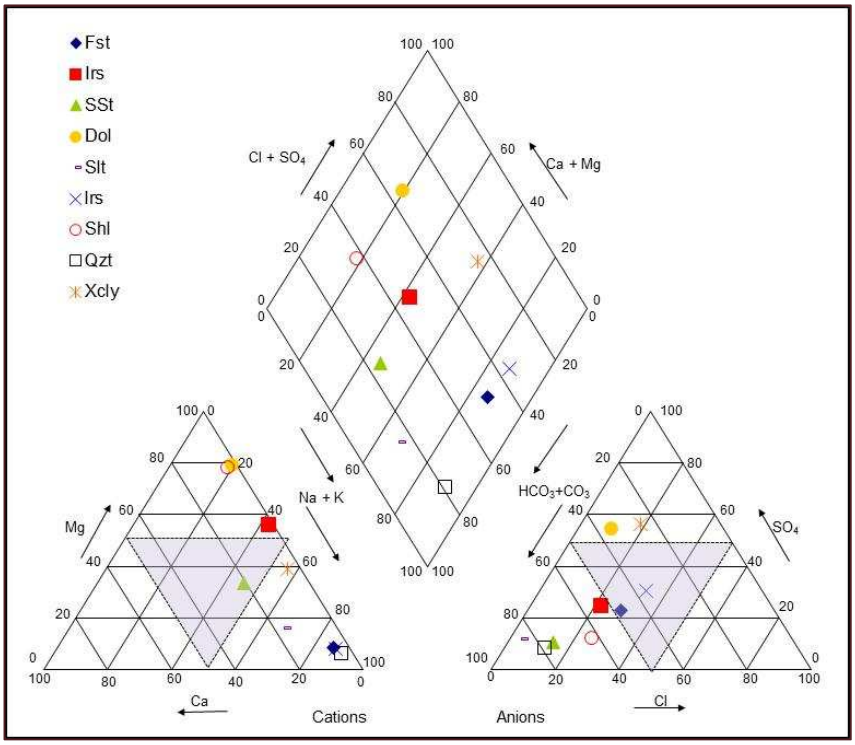

Figure 15: Piper Plot of Laboratory Leachates.

6. Conclusions and Mining Implications

6.1 Conclusions

The AMD investigations and assessments for Deposit C were undertaken by:

1. Developing a conceptual model to facilitate and define the potential for AMD within the footprint of the open pit. The test work included in this part of the investigations entailed:
   A. Analysis of S occurrences and populations recorded during the exploration programs.
   B. Bulk sampling preliminary AMD assessment.
2. The development of a supplementary sampling program targeting areas identified with PAF materials in Step 1.
3. The supplementary AMD assessment to confirm the observations made in the conceptual model.

The findings of the above investigations and assessments complement each other and indicate that:

- The materials to be disturbed by mining are characteristically composed of key deposit fingerprint minerals including iron silicates with subsequent iron oxides such as hematite and goethite. Hematite is dominant in both the ironstone sparse oolite and the ferruginous sandstones. The highest concentrations of magnetite occur in the siltstones. Clay minerals including kaolin, muscovite, illite and chlorite are significant and larger concentrations of these are found in the sandstones and siltstones.
- Except for enrichment by iron and arsenic, most of the samples are not distinctively enriched with any particular element. The highest enrichment by iron is typical in the ironstone sparse oolites at depths between 10m and 40m below surface. Enrichment with sulfur (to about 24 fold) was observed in about 270 samples, particularly among the ironstone sparse oolites and dolerites at depths between 20m and 40m below ground level.
- Based on sulfide concentration, PAF materials occur sporadically, are highly localised and confined to about nine locations five of which occur either below or outside the confines of the proposed open pit (refer Figure 18 overleaf).
- PAF characteristics, within the proposed open pit (~37.0m depth) were only observed in two samples (RR00443 and RR00444, Figure 16). This zone was indicated on Figure 10 and it is likely these materials will be removed if mining extends to depths between 30m to 40m. One other sample (AMDAC21, dolerite) to the north of the proposed pit was classified as having PAF characteristics.
- Samples AMDAC-07, AMDAC-08, AMDAC-13, AMDAC-19 and AMDAC-20 targeted potential lateral extensions of PAF zones identified during earlier programs (Figure 16). None of these were characterised as PAF during the supplementary AMD assessment which confirms that the PAF materials located nearby are highly localised and confined to relatively small zones.
- Laboratory leachates are dominantly circumneutral (pH 6.5) with pH ranging between 5.4 and 7.8. The highest pH (7.8) was observed in deep beaded shales whilst the lowest occur in the ironstone sparse oolites and ferricrete sandstones located between the surface and 25m depth. Whilst major ions are in the order of magnesium>sodium>potassium>calcium, trace metals are in the order of Fe>Al>Mn with no significant concentrations of toxic elements such as cadmium and chromium. Although most of the lithotypes are enriched by arsenic, mobility of this element in solution is very low with an average concentration of 2.22µg/L. Iron activity tends to be higher at near surface and intermediate levels and decreases slightly with depth.

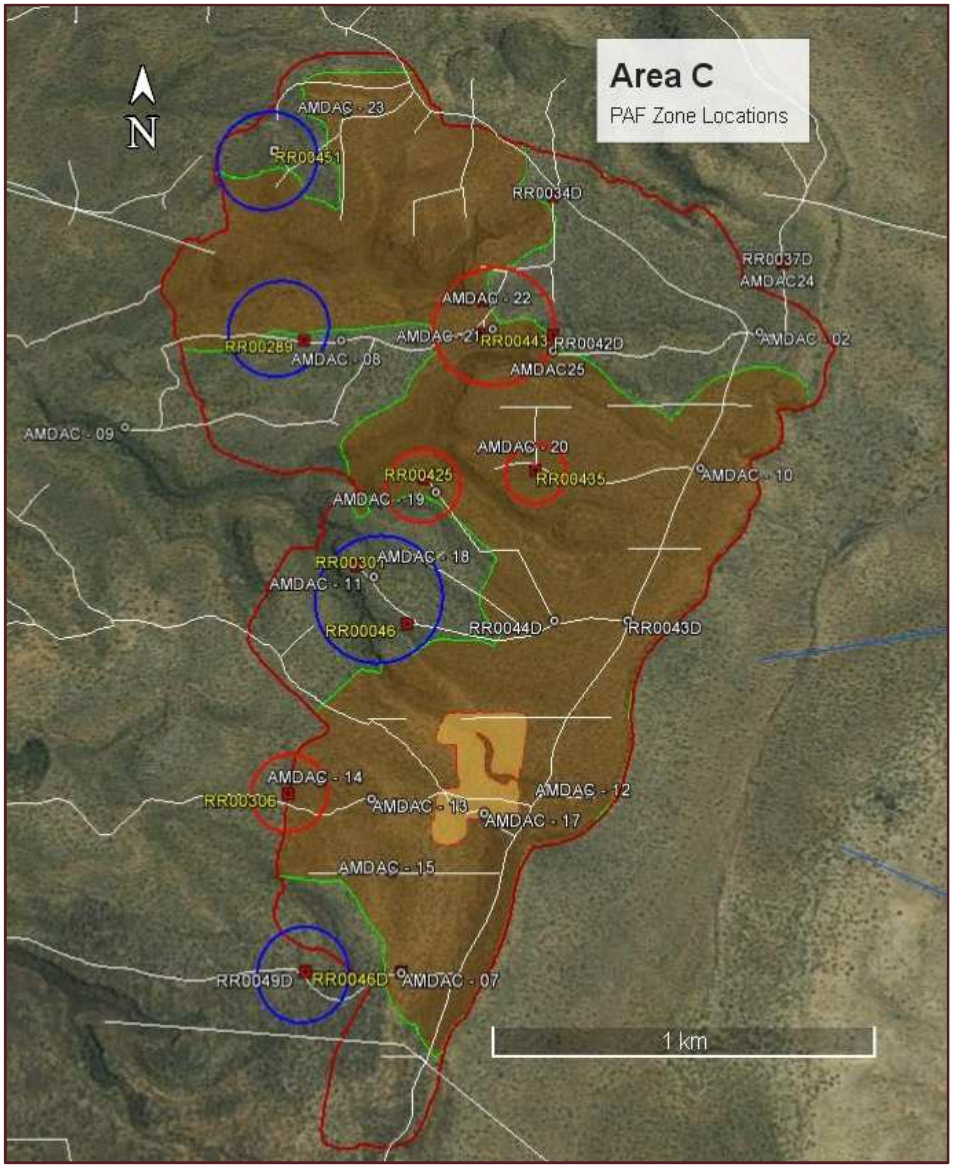

Figure 16: Locations of PAF Zones.

(Note: Sample locations in blue are outside of the proposed pit footprint whilst those in red are inside or would be marginally exposed in the basement or sidewalls of the open pit).

In summary:

- The majority of waste lithotypes to be produced during mining is considered to be geochemically benign. This applies to mine waste materials derived from *above-, in-ore and below-ore zones*.
- Disturbance of PAF material at the northern part of Deposit C will occur only when the pit expands from 30m to 40m below surface. According to the proposed mining schedule (Figure 17), areas which contain PAF materials will be mined between years 4 and 6. Further site-specific characterisation, demarcation, prevention and remediation measures will commence in year 3.

6.2 Mining Implications

6.2.1 Risk Assessment Methodology

To ascertain which factors may impact on environmentally sensitive receptors and which may require on-going management, a risk assessment was undertaken in accordance with the Australian Standard AS4360: Risk Management Standard. The hierarchy of risk controls considered are:

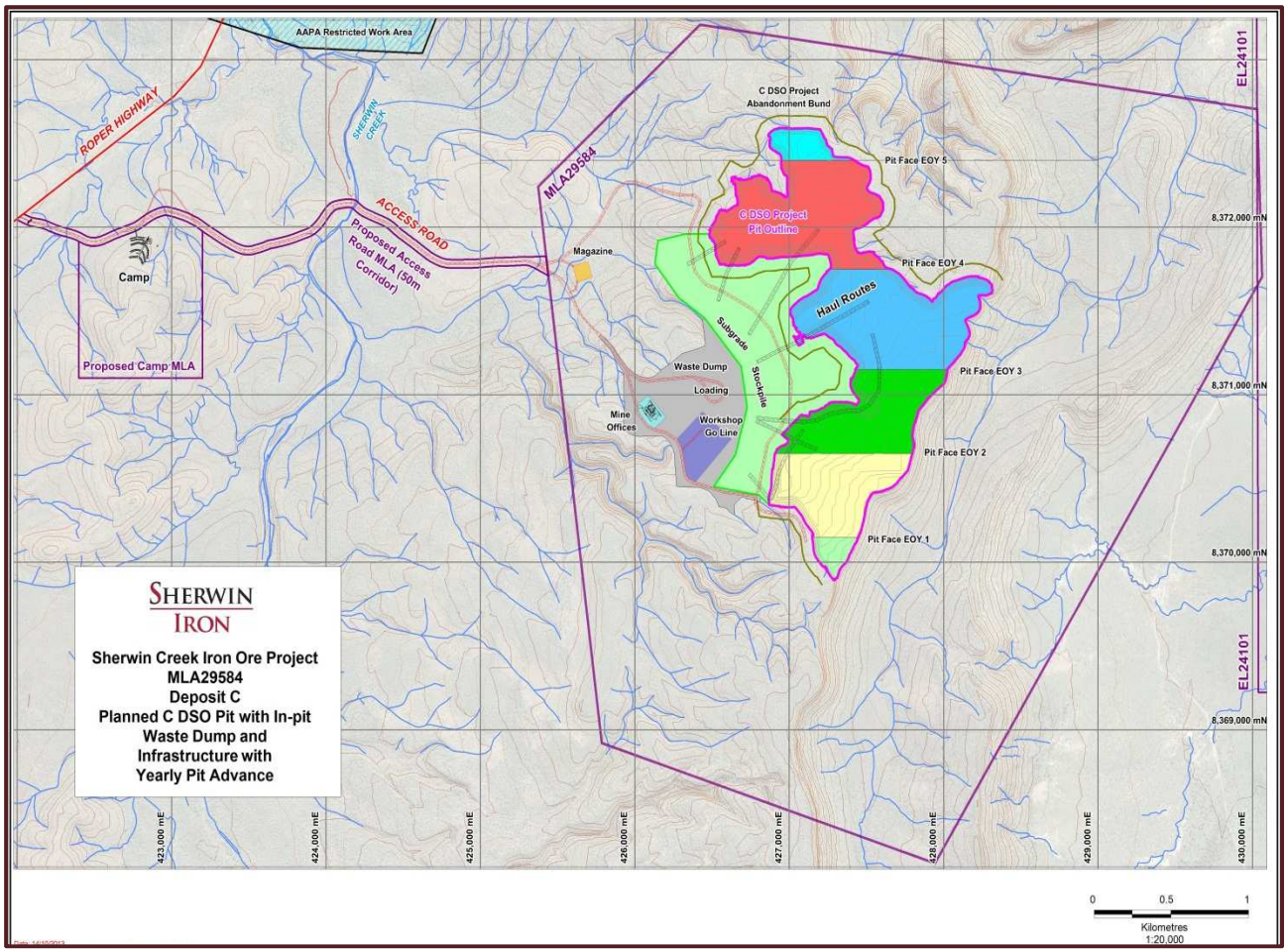

Figure 17: Mining Schedule.

- ***Elimination:*** stop using the equipment, or stop undertaking the procedure/activity causing the risk (e.g. comprehensive surface /ground water management plan).
- ***Substitution:*** use an alternative substance, equipment or process which poses less risk (e.g. implement different more technologically driven excavations to recover resources and differentiate PAF materials).
- ***Isolation:*** separate receivers from the source of the risk (e.g. implement compaction and ground-sealing activities to prevent surface water percolation).
- ***Engineering controls:*** reduce exposure to the risk by making physical changes to equipment, procedures or the work environment (e.g. installing equipment in areas with low risk of acidity and/or alkalinity).
- ***Change work practices:*** adopt work procedures which minimise exposure to the risk (e.g. where feasible zone and preserve areas with high PAF risk).

Table 17: Risk Likelihood Classification.

Level	Likelihood	Description	Criteria
A	Rare:	Practically impossible, will only occur in exceptional circum-stances. Has never occurred in the industry.	0-1%
B	Unlikely:	Could occur at some time but highly unlikely. Has occurred in the industry previously.	1-10%
C	Moderate:	Might occur at some time. Has occurred in associated com-panies previously.	11-50%

Level	Likelihood	Description	Criteria
D	Likely:	Known to occur or will probably occur in most circum-stances. Has occurred several times/year in associated companies.	51-90%
E	Almost Certain:	Common or repeating occurrence. Is expected to occur several times/year in any associated business.	91-100%

Table 18: Risk Consequence Classification.

Level	Consequence	Description
1	Insignificant	No measurable impact on the environment. No injuries. Low-nil financial loss.
2	Minor	Minor, temporary environmental impact. No publicity likely and no stakeholder concerns. First aid treatment required. Medium-low financial loss.
3	Moderate	Substantial temporary or permanent minor, localised environmental damage. Stakeholder enquires (this may include government, unions or public). Medical attention required. High-medium financial loss.
4	Major	Substantial or permanent environmental damage. Prosecution possible. Loss of company credibility and high stakeholder interest. Permanent injuries. High financial loss.
5	Catastrophic	Widespread severe and permanent environmental damage. Major stakeholder and media interest. Prosecution likely. Permanent injury or death. Extreme financial loss.

Table 19: Risk Assessment Matrix.

Likelihood		Consequence				
		1	2	3	4	5
		Insignificant	Minor	Moderate	Major	Catastrophic
E	Almost certain	11	16	20	23	25
D	Likely	7	12	17	21	24
C	Probable	4	8	13	18	22
B	Unlikely	2	5	9	14	19
A	Rare	1	3	6	10	15
	Extreme risk, intolerable.					
	High risk, intolerable or tolerable.					
	Medium risk, tolerable or acceptable.					
	Low risk, acceptable.					

6.2.2 Risk Assessment

Appropriate site-specific management of PAF materials should be undertaken to ensure that there is no impact of acid mine/metalliferous drainage (AMD) to the environment resulting from the mining and processing of ore. Dewatering of the open pit to facilitate mining will not be required which minimizes the risk of exposing PAF materials which then may come into contact with mine influx.

In the absence of large scale PAF materials, the key risk relates to the potential for ground water to be impacted by infiltration and seepage from the open pits during mining and backfill after closure. These potential seepages or infiltrating waters may transport oxygen into prevailing anoxic environments and may migrate through natural undisturbed PAF bodies underlying the open pit. However, PAF bodies are relatively small and isolated and evaporation exceeds rainfall in the area by several orders of magnitude which will limit the quantity of water that may infiltrate through the base of the open pit. Rain falling into the open pit may also be diverted away from areas where PAF bodies are known to exist.

Small quantities of PAF materials exist in the north-western area of the proposed open pit and these, if disturbed, may generate acidity. Mining at this location is scheduled between years 4 and 6, thus specific assessments, controls and preventive and remediation measures will commence in year 3.

Table 20 details the key activities that may impact the environment and includes consideration of social and cultural aspects and include mitigation and control strategies/management measures detailed below.

6.2.3 AMD Mitigation and Management

Assessments indicated that Deposit C, due to its mineralogical characteristics and low content of sulfide-bearing materials, has a low likelihood of generating AMD and further investigations such as continuous large scale investigation of waste materials to define their PAF or NAF characteristics (e.g. kinetic testing) are not warranted. It is recommended that ABA testing be undertaken at a rate of 3 samples per hectare once the base of the pit reaches 30m depth. Sampling density should be increased to between 5 and 10 samples per hectare once mining expands to the northern part of the open pit. The main concern is the potential for AMD in areas where PAF materials, albeit localised, were confirmed. The management of these areas should include:

- Site demarcation, control and monitoring.
- Upfront engineering/scientific approaches to identify, predict, prevent and monitor potential AMD formation.
- On-going risk assessment to define impacts on the local ecosystems and downstream environments.

Site specific methods to identify and manage PAF materials and consequently formation of AMD should include (from year 3 onwards):

- During grade control, obtain samples from depths of 30m and deeper and undertake ABA testing and assessment to verify the lateral and vertical extent of these PAF materials identified earlier. The findings of this sampling and analysis program should be used to improve delineation of both PAF/NAF waste and ore materials and assist in defining further management processes including the construction of cells to encapsulate any PAF materials.
    - The block model should be updated frequently to improve waste rock/ore body delineation with regard to NAF/PAF characterisation.
    - Define NAF/PAF characterisation in exposed floors and sidewalls of the open pit.
    - Where PAF materials are encountered, materials should be segregated and managed to prevent interaction with particularly rainfall in the absence of ground water influx.

Table 20: Risk Assessment, Mitigation and Management.

Risk Identification and Analysis				Risk Rating			Control Strategy Measures	Risk Rating			Further Actions
Number	Issue	Cause	Impact	L	C	R		L	C	R	
Surface Soils, Surface Water and Groundwater											
Activity: The mining method to be employed is bench mining and backfilling.											
Social/Cultural											
1	Social/Cultural Environmental: Tourism	Open Pit	Visual impact	**B**	3	**M**	Restrict/control access to mine infrastructure particularly plant, WRDs and the open pit. Provide fencing if required and where needed.	B	2	**L**	Monitoring.
AMD											
2	Excavation within and/or in proximity to PAF materials	Open Pit	Contamination of surface and ground water	D	3	H	Demarcation and progressive excavation and implementation of immediate measures such as burial, sealing and compaction to contain/encapsulate/cover and prevent PAF materials to oxidise. Benching where possible should be excavated in lengths that permit easy, extraction, remediation and closing. Where PAF is exposed sealing and compaction of the sides and base of the excavation should be undertaken before backfilling. Implementation of construction methods to prevent long-term PAF exposure to oxygen (e.g. sheet piling) should be considered.	B	2	L	Development of localised surface covers to protect PAF zones. Construction of trenches in which PAF materials can be disposed of and covered. These will be located preferably where backfilling can proceed immediately.
3	Removal of overburden, ore and waste rocks.		Pit excavation : Expose PAF to the atmosphere and trigger oxidation	**D**	**3**	**H**		**B**	2	**L**	Implement cover systems to contain and encapsulate PAF materials and monitor.
			Expose/disturb PAF materials	D	3	**H**		**B**	2	**L**	Monitoring effectiveness of covers and predict future conditions of the remediated materials.
Extraction of Iron Ore											
4	Extraction of Ore	Benching and Ore extraction.	Influx of oxygen and/or water into PAF bearing zones.	4	**3**	H	Demarcation and benching to selectively remove ore body and collect exposed and fractured PAF materials.	**B**	2	**L**	Monitoring, demarcation and implementation of remediation measures to prevent oxidation of exposed PAF materials. Where relevant, implement surface covers and/or waste sheet piling to cover PAF materials.
5	Interconnection of PAF with surface/rain-runoff waters via bench excavations.		Oxidation of PAF materials and production of acid solutions.	**C**	4	**H**	Capping and compacting of exposed PAF materials.	**B**	2	L	Immediate capping and compaction of exposed PAF materials. Monitoring of acidity forming and updating of data to observe resource recovery and environmental impact priority actions.

Risk Identification and Analysis				Risk Rating			Control Strategy Measures	Risk Rating			Further Actions
Number	Issue	Cause	Impact	L	C	R		L	C	R	
Surface Soils, Surface Water and Groundwater											
6	Acid water discharge		Impact to receiving overburden and water bodies	C	3	H	Where needed AMD should be managed and treated by using daily and inline monitoring to observe changes in key parameters such as pH. If pH<5.0 and excess acidity, then: ▪ Neutralise solutions to pH (6.5 to 8.5) using neutralising agents such as calcite pellets, lime sands, etc. ▪ Removal of metals using suitable filtration or flocculation methods.	B	2	L	Investigate the need to implement lined evaporation ponds. Assess impacts of acid and /or saline residual waters in the overburden, waste rock and ore bodies. Findings will aid in implementing other uses of residual water such as in dust suppression activities.
Notes: L denotes Likelihood, C Consequence and R Risk Rating.											

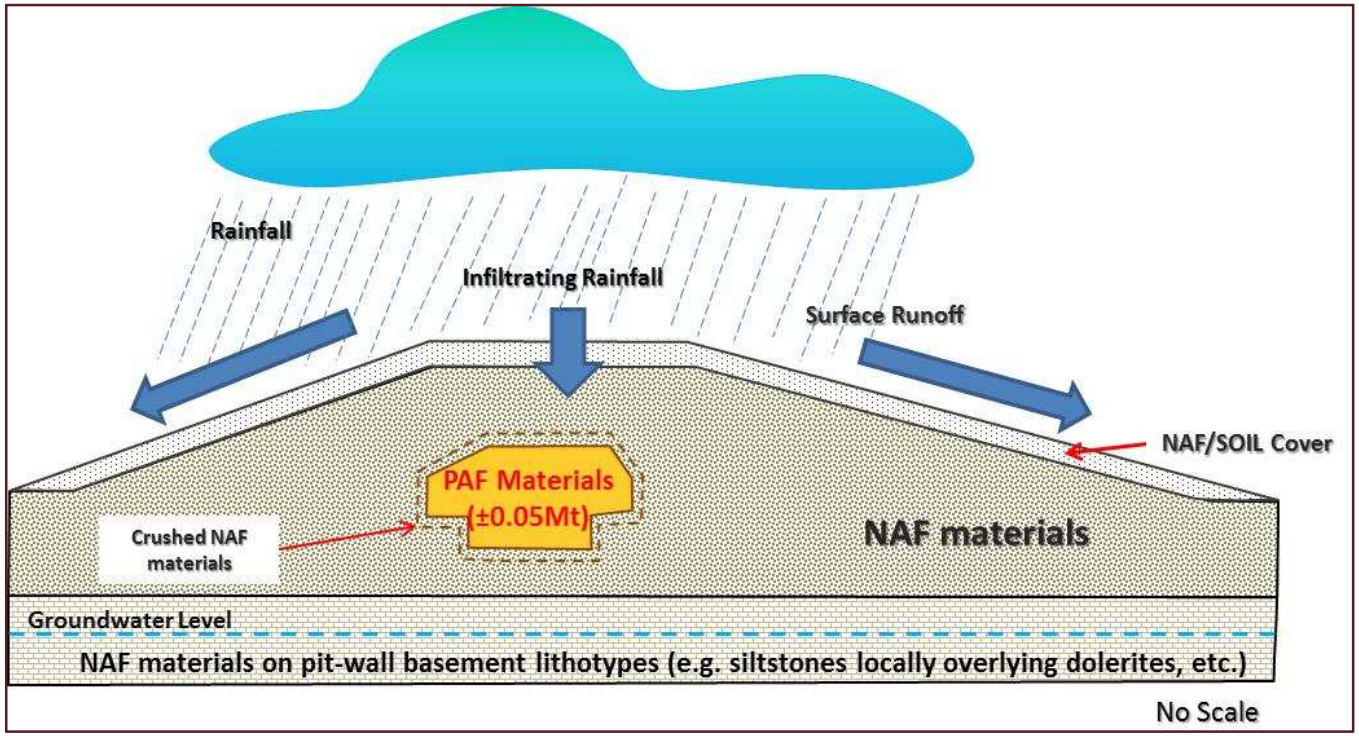

Figure 18: Idealised PAF Encapsulation.

- PAF materials should be disposed of in purpose designed and built encapsulation cells and adequately covered and compacted. Excavated NAF materials should be used to construct engineered beds and/or cells for the disposal by encapsulation of PAF materials to limit oxygen and water infiltration. Encapsulation of PAF materials with NAF materials could be accomplished as shown in the conceptual model depicted in Figure 18.
- The prediction of post-closure drainage geochemistry should be updated as required.
- Refine waste management approaches and included conceptual models to incorporate new observations and findings.
- Monitoring ground water qualities in shallow and deep bores constructed up and downstream of the encapsulation cells, if and where required.

If ongoing waste monitoring detects increased concentrations of PAF materials then the approach to PAF management should be amended to include:

- The implementation of a standard operating procedure for PAF management.
- An improved PAF encapsulation model which would require further investigations.

- Post-mining, closure and rehabilitation will include standard processes and methodologies to prevent or minimize exposure of PAF materials to the atmosphere. Monitoring should be trailed by remediation if and where required.

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Appendices

Appendix A: XRF Assessment (Exploration Program)

Appendix B: Quantitative X-ray Diffraction Analysis of Drill Chips

Appendix C: XRD and XRF Analysis of Core Samples

Appendix D: Laboratory Certificates (ABA and Leachate Tests Analysis)

Appendix A:
XRF Assessment (Exploration Program)

Appendix A - II:
XRF Assessment

Appendix B:

Quantitative X-ray Diffraction Analysis of Drill Chips

Appendix D:

Laboratory Certificates (ABA and Leachate Tests Analysis)

IDENT	Job number	Project code	paste pH	ANC	MPA	NAPP	NAG (pH7.0)	NAG_pH	pH	EC	TDS	Alkalinity	HCO_3	CO_3	OH	Cl	S
UNITS			units	kg/T H_2SO_4	kg/T H_2SO_4	kg/T H_2SO_4	kg/T H_2SO_4	units	units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ppm
SCHEME			EA	ANC	ANC	ANC	NAG	NAG	ALK1	ALK1	TSSTDS	ALK1	ALK1	ALK1	ALK1	FIAS_4	G400I
AMDAC02S	NT36723	SHD138	6.3	0.84	0.24	<0.01	3.44	6.0	6.3	13	90	1	1	<1	<1	1.1	80
AMDAC07S	NT36723	SHD138	6.2	2.04	0.25	<0.01	<0.01	6.9	6.2	18	110	1	1	<1	<1	1.6	80
AMDAC08S	NT36723	SHD138	7.8	43.4	1.59	<0.01	<0.01	7.8	7.8	81	110	38	38	<1	<1	9.5	520
AMDAC09S	NT36723	SHD138	5.7	2.51	0.80	<0.01	<0.01	7.0	5.7	26	130	<1	<1	<1	<1	1.3	260
AMDAC10S	NT36723	SHD138	5.5	0.85	0.51	<0.01	0.39	6.7	5.5	17	<10	<1	<1	<1	<1	0.9	160
AMDAC11S	NT36723	SHD138	6.9	4.57	1.30	<0.01	0.24	6.9	6.9	51	170	9	9	<1	<1	5.1	420
AMDAC12S	NT36723	SHD138	7.0	1.77	0.14	<0.01	5.65	6.2	7.0	21	100	11	11	<1	<1	1.2	40
AMDAC13S	NT36723	SHD138	5.9	2.29	0.05	<0.01	0.24	6.8	5.9	12	140	1	1	<1	<1	1	<20
AMDAC14S	NT36723	SHD138	8.0	2.89	1.50	<0.01	0.48	6.6	8.0	40	180	42	42	<1	<1	1.3	480
AMDAC15S	NT36723	SHD138	6.4	2.12	0.21	<0.01	<0.01	7.0	6.4	13	110	2	2	<1	<1	1	60
AMDAC16S	NT36723	SHD138	5.7	1.48	0.63	<0.01	<0.01	7.0	5.7	11	180	1	1	<1	<1	1	200
AMDAC17S	NT36723	SHD138	5.6	1.26	0.54	<0.01	<0.01	7.3	5.6	19	180	<1	<1	<1	<1	1.6	180
AMDAC18S	NT36723	SHD138	7.0	4.13	0.09	<0.01	<0.01	7.2	7.0	24	280	13	13	<1	<1	1.9	20
AMDAC19S	NT36723	SHD138	7.0	6.24	1.08	<0.01	<0.01	7.1	7.0	46	330	10	10	<1	<1	6.7	360
AMDAC20S	NT36723	SHD138	7.2	9.48	3.31	<0.01	0.24	6.8	7.2	58	140	23	23	<1	<1	5.2	1080
AMDAC21S	NT36723	SHD138	6.5	2.70	11.3	8.56	11.7	3.8	6.5	58	150	2	2	<1	<1	1.8	3680
AMDAC22S	NT36723	SHD138	6.9	38.5	3.88	<0.01	0.34	6.8	6.9	65	40	4	4	<1	<1	3	1260
AMDAC23S	NT36723	SHD138	7.2	2.61	1.13	<0.01	6.56	5.0	7.2	27	140	20	20	<1	<1	0.7	360
AMDAC24S	NT36723	SHD138	5.4	1.42	0.74	<0.01	0.34	6.7	5.4	22	20	<1	<1	<1	<1	1.4	240
AMDAC25S	NT36723	SHD138	6.0	3.46	0.20	<0.01	4.89	6.0	6.0	8	100	1	1	<1	<1	0.5	60
AMDAC26S	NT36723	SHD138	5.5	3.16	0.47	<0.01	6.52	5.6	5.5	22	130	<1	<1	<1	<1	3	160

IDENT	Ca_F	K_F	Mg_F	Na_F	SO_4_F	Al_T	Al_T	As_T	Cd_T	Cr_T	Cu_T	Fe_T	Fe_T	Mn_T	Mn_T	Ni_T	Pb_T	U_T	Zn_T
UNITS	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
SCHEME	W108I	W108I	W108I	W108I	W108I	W200M	W200I	W200M	W200M	W200M	W200M	W200M	W200I	W200M	W200I	W200M	W200M	W200M	W200M
AMDAC02S	<0.1	0.6	<0.1	1.6	0.9	0.9	N.A.	0.1	<0.02	<0.1	0.04	<2	N.A.	1.38	N.A.	<0.01	0.02	<0.001	<0.1
AMDAC07S	<0.1	1.6	<0.1	1.8	2.2	0.9	N.A.	0.1	<0.02	<0.1	0.05	2	N.A.	39.1	N.A.	0.26	<0.01	0.001	<0.1
AMDAC08S	0.5	1.5	7.4	2.4	6.1	58.2	N.A.	7	<0.02	<0.1	0.1	>LWR	1.05	45.5	N.A.	0.09	0.02	0.01	<0.1
AMDAC09S	0.1	0.6	0.6	1.3	5.4	1.7	N.A.	0.2	<0.02	<0.1	0.03	<2	N.A.	>LWR	1.33	2.16	<0.01	0.004	0.3
AMDAC10S	<0.1	0.7	0.1	1.5	2.2	1	N.A.	<0.05	<0.02	<0.1	0.02	<2	N.A.	126	N.A.	0.23	<0.01	<0.001	0.4
AMDAC11S	<0.1	1.1	3.7	1.9	9.5	91.5	N.A.	1.6	<0.02	<0.1	0.04	>LWR	1.2	36	N.A.	0.11	0.01	0.004	0.4
AMDAC12S	<0.1	2	<0.1	1.6	1.1	106	N.A.	0.15	<0.02	0.1	0.1	46	N.A.	0.79	N.A.	0.04	0.02	0.004	3.3
AMDAC13S	<0.1	0.5	<0.1	1.4	1	1.5	N.A.	0.1	<0.02	<0.1	0.03	72	N.A.	5.81	N.A.	<0.01	<0.01	<0.001	<0.1
AMDAC14S	<0.1	7.6	0.2	1.7	6.6	>LWR	1.86	10.5	<0.02	1	0.12	>LWR	1.45	24	N.A.	0.3	0.18	0.138	0.6
AMDAC15S	<0.1	1.4	<0.1	1	1	3.4	N.A.	0.1	<0.02	<0.1	0.02	16	N.A.	1.66	N.A.	<0.01	<0.01	0.003	<0.1
AMDAC16S	<0.1	0.6	<0.1	1	0.9	1.3	N.A.	<0.05	<0.02	<0.1	<0.01	<2	N.A.	27.4	N.A.	0.14	<0.01	<0.001	0.6
AMDAC17S	<0.1	1	0.2	1.7	1.5	2	N.A.	0.05	<0.02	<0.1	0.02	<2	N.A.	157	N.A.	0.63	<0.01	0.003	<0.1
AMDAC18S	<0.1	0.6	0.5	2.5	2	98.3	N.A.	2.1	<0.02	0.1	0.25	>LWR	2.95	29.9	N.A.	0.08	0.03	0.015	2.7
AMDAC19S	<0.1	0.7	3.4	1.5	6.7	101	N.A.	2.9	<0.02	0.1	0.51	>LWR	8.35	27.5	N.A.	0.12	0.06	0.013	1.2
AMDAC20S	<0.1	1.8	2.6	4.7	9.2	94.5	N.A.	3.35	<0.02	<0.1	0.16	>LWR	1.5	24.1	N.A.	0.22	0.01	0.023	1.1
AMDAC21S	0.1	1.1	4.6	1.2	19.1	68.8	N.A.	1.2	<0.02	<0.1	<0.01	230	N.A.	19.7	N.A.	0.15	0.02	0.005	<0.1
AMDAC22S	0.2	0.7	5.4	1.2	17.1	24.2	N.A.	1.65	<0.02	<0.1	<0.01	96	N.A.	135	N.A.	0.3	0.01	<0.001	<0.1
AMDAC23S	<0.1	3.9	<0.1	1.2	3.3	702	N.A.	5.7	<0.02	0.5	0.04	298	N.A.	2.79	N.A.	0.12	0.06	0.085	2.4
AMDAC24S	<0.1	1.3	<0.1	1.6	3.6	3.7	N.A.	0.1	<0.02	<0.1	0.11	8	N.A.	362	N.A.	4.93	<0.01	0.002	2.5
AMDAC25S	<0.1	0.7	<0.1	0.5	0.3	1.2	N.A.	0.05	<0.02	<0.1	<0.01	<2	N.A.	0.24	N.A.	<0.01	<0.01	<0.001	0.6
AMDAC26S	<0.1	0.8	<0.1	2.6	2.1	1.2	N.A.	0.1	<0.02	<0.1	0.07	30	N.A.	7.98	N.A.	0.84	<0.01	<0.001	0.1