Acid and Metalliferous Drainage (AMD) Management Plan 2020-2023

Nathan River Project

Nathan River Resources

Revision No 4
December 2019

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Report

Title:	Acid and Metalliferous Drainage (AMD) Management Plan: Nathan River Project Nathan River Resources Revision No 3
File:	PES19017
Author(s):	Carel van der Westhuizen
Client:	METServe on behalf of Nathan River Resources
Contact(s):	Dave Moss and Jim Barker
Synopsis:	This document details the Acid and Metalliferous Drainage (AMD) Management Plan for the Nathan River Project of Nathan River Resources of Nathan River Resources (NRR) based upon a detailed assessment of the acid metalliferous/mine drainage (AMD) and metal leaching potential of waste rocks and the potential impacts to the local and wider environment. It takes due cognisance of the conditions of approval by the then Department of Sustainability Environment, Water, Population and Communities (SEWPaC) and the then Northern Territory Department of Mines and Energy. This document takes due cognisance of all the earlier Mine and AMD Management Plans to date and has been updated to incorporate the comments of the Peer Review by Amanzi Consulting in November 2019 and the Department of Environment and Energy in December 2019.

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Revision

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Abbreviations

Abbreviations	
ADWG	Australian Drinking Water Guideline
AHD	Australian Height Datum
AMIRA	Australian Mineral Industries Research Association
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASLP	Australian Standard Leaching Procedure
CSM	Conceptual Site Model
DO	Dissolved Oxygen
DoE	Department of Environment
DPIR	Department of Primary Industry and Resources
DSO	Direct Shipping Ore
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EMS	Environmental Management System
GDE	Groundwater Dependent Ecosystem
KYM	Kyalla Siltstone Member
LGO	Low Grade Ore
MCP	Mine Closure Plan
MMP	Mine Management Plan
MSM	Moreak Sandstone Member
NRR	Nathan River Resources
NT EPA	Northern Territory Environment Protection Authority
ORP	Oxidation Reduction Potential
RBIOP	Roper Bar Iron Ore Project
SEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities
SIM	Sherwin Ironstone Formation
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility
TSS	Total Suspended Solids
WDL	Waste Discharge Licence
WDR	Western Desert Resources

Abbreviations	
WMMP	Water Management and Monitoring Plan
WRD	Waste Rock Dump
Units	
cm	centimetre
d	day
ha	hectare
hr	hour
kg	kilogram
km	kilometre
m	metre
mm	millimetre
mg/L	milligram per litre
µg/L	micro-gram per litre
min	minute
yr	year
s	second
t	tonnes
µS/cm	micro-Siemens per centimetre

Discipline

Acronym	Parameter Definition/(Determination)	Unit
ABA	The acid-base accounting test was developed in 1974 to evaluate coal mine waste and was modified by Sobek *et al*. in 1978. Acid-Base Accounting is a test to assess the potential of a material to produce both acid and neutralisation potential.	
AC	Acid Consuming; materials with a capacity to neutralise acid.	kgH_2SO_4/ton
AFP	Acid Formation Potential is the potential for a material to produce acid.	kgH_2SO_4/ton
AMD	Acid Metalliferous/Mine Drainage – originates when sulfide material is exposed to the atmosphere. This causes the formation of sulfuric acid and the potential outflow of acidic and usually highly metal-rich water into the environment. Potential sulfide-bearing material includes waste rock from overburden, interburden, and processed ore (tailings).	
ANC	Acid Neutralising Capacity (Laboratory Analysis) - is the measure of acid neutralising capacity, usually expressed by carbonates (e.g. calcite and dolomite) and silicates.	kgH_2SO_4/ton
APR	Acid Potential Ratio (Calculation) – is the ratio of ANC/MPA and is used to classify material as either NAF or PAF (see definitions below).	
APP	Acid producing potential; also referred to acid generating potential (AGP).	kgH_2SO_4/ton
ARD	Acid Rock Drainage – the use of this term indicate natural weathering and oxidation unmined outcrops of sulfide bearing materials.	
CaO	Calcium Oxide.	%
EDS	Energy Dispersive Spectroscopy (EDS) Analyses	

Acronym	Parameter Definition/(Determination)	Unit
Fe	Iron	
GAI	Geochemical Abundance Index.	
Kinetic Testing	Tests results provide information on the rate of sulphide reaction over time, time periods for reaction, and control techniques which can optimise treatment and control to address the specific severity and duration of reaction.	
LC	Low Capacity.	
MgO	Magnesium Oxide.	%
MPA	Maximum Potential Acidity or APP (Acid Production Potential) (Calculation) - It is determined by multiplying the Sulfide-S values (in %) by 30.6, which accounts for the reaction stoichiometry for the complete oxidation of pyrrotite and pyrite by O_2 to $Fe(OH)_3$ and H_2SO_4. MPA does not take into account the effect of any acid consuming materials in the rock material.	kgH_2SO_4/ton
NAF	Non Acid Forming (Calculation). Materials are classified as NAF if either: - Sulfide-S < 0.3%, or - Sulfide-S ≥ 0.3% and NAPP is negative with ANC/MPA ≥ 2.0 (see also PAF definition below)	
NAG	Net Acid Generation or NAP (Net Acid Production) (Laboratory Analysis) –hydrogen peroxide is used to accelerate the oxidation of sulphides present in the material. The acid produced may be partially or totally consumed by acid neutralising components in the material. The pH of the solution is determined and then titrated to pH 7. This gives a value for the Net acid or neutralizing potential of the sample.	kgH_2SO_4/ton
NAPP	Net Acid Producing Potential (Calculation) - NAPP = MPA - ANC. Conceptually, a negative NAPP indicates all acid produced is neutralised and a positive NAPP indicates the material is net acid producing.	kgH_2SO_4/ton
NNP	Net Neutralising Potential (Calculation) - NNP = ANC - MPA. Conceptually, a positive NNP indicates all acid produced is neutralised and a negative NAPP indicates the material is net acid producing. NNP is a conservative measure as it tends to overestimate the acid producing potential because it does not differentiate between acid producing and non-acid producing forms of sulfur.	kgH_2SO_4/ton
NPR		
PAF	Potential Acid Forming (Calculation). Materials are classified as PAF if either: - Sulfide-S ≥ 0.3% and NAPP is positive, or - Sulfide-S ≥ 0.3% and NAPP is negative, but ANC/MPA < 2.0 (see also NAF definition above).	
SEM	Scanning Electron Microscopy (SEM) Analyses	
SOR	Sulfide Oxidation Rate - Sulfide reaction over period of time.	$mgSO_4$/kg/ week
Static Testing	A static test determines both the total acid generating and total acid neutralizing potential of a sample.	
Sulfide-S	Sulfide Sulfur (Calculation) – is the sulfur in the material present as sulphide. Sulfide Sulfur = Total-S - Sulfate-S	%(w/w)
Total-S	Total Sulfur (Laboratory Analysis) – is the total sulfur in a material in all its forms.	%(w/w)
UC	Uncertain Waste Rock Classification	

Executive Summary

Nathan River Resources (NRR) acquired the Western Desert Resources (WDR) leases for the Roper Bar Iron Ore Project (RBIOP) in 2017. METServe assisted NRR with a Mine Management Plan (MMP) to complete works on site to remove redundant infrastructure and material stockpiles. NRR lodged a subsequent MMP early this year to facilitate small scale extraction of iron ore, approximately 1 Mt of Direct Shipping Ore, during 2020 and 2023 from the existing F-East Pits where the ore body was exposed previously. Waste rock will be stored in the existing F-East Waste Rock Dumps and the potentially acid forming (PAF) waste will be stored in the existing PAF storage cell on the F-East WRD.

The management options detailed in this Acid Mine/Metalliferous Drainage Management Plan (AMDMP) are designed to promote best practice and continuous awareness and environmental improvement by means of a life-cycle approach towards AMD management and detailed ecological and human health risk assessments documented in several assessments during the environmental approvals process and thereafter. The framework articulated in these documents aims to focus on early identification of AMD risk to focus the effort on prevention or minimisation rather than control or treatment. It also allows for frequent reviews and continual improvement.

The AMD risk assessments to date indicate that with appropriate design and operational control measures, the residual AMD risk is medium at worst and manageable with effective controls. Any residual risk would be monitored during implementation of the AMDMP to confirm that the design and operational control measures are effective.

This AMDMP, amended in accordance with the findings of the November 2019 peer review by Amanzi Consulting and subsequent comments by the Department of Environment and Energy in December 2019, supports and is to be included in the 2020-2023 Mine Management Plan.

1. Introduction

1.1 Project Description

Nathan River Resources (NRR) acquired the Western Desert Resources (WDR) leases for the Roper Bar Iron Ore Project (RBIOP) in 2017. METServe assisted NRR with a Mine Management Plan (MMP) to complete some initial works on site to remove redundant infrastructure and some material stockpiles. NRR lodged a subsequent MMP early this year to facilitate small scale extraction of iron ore; the proposed activities are (extracted from the MMP):

Mining will continue at the existing F-East Pits (Figure 1.1) where the ore body was exposed previously. Approximately 1 Mt of Direct Shipping Ore (DSO) will be mined during the plan period (2020-2023). Waste rock will be stored in the existing F-East waste rock dumps (WRD) and the potentially acid forming (PAF) waste will be stored in the existing PAF storage area on the F-East WRD.

Figure 1.1: Mine Layout.

The 2020-2023 mining plan pertains to removal of approximately 150,000 t of DSO material in the F-East Pits 1 (FE1) and 2 (FE2) which was blasted previously but remained in-situ combined with approximately 850,000 t of DSO ore that require blasting. Low grade ore (LGO), NAF and PAF wastes will be concurrently mined and extracted.

The pit shell (Figure 2.2) for the 2020-2023 mining plan is approximately 3,090 m long, up to 165 m wide and up to 77 m deep. The shape of the pit is constrained by the proximity of the Towns River to the north.

Initially, production will focus on the already blasted material in FE2 and FE1. A hydraulic excavator and fleet of dump trucks will be used for the mining operations. Following removal of the blasted materials, drill and blast operations will be required for further production. It is anticipated that up to 2 blasts may be required per week for the currently planned production rate.

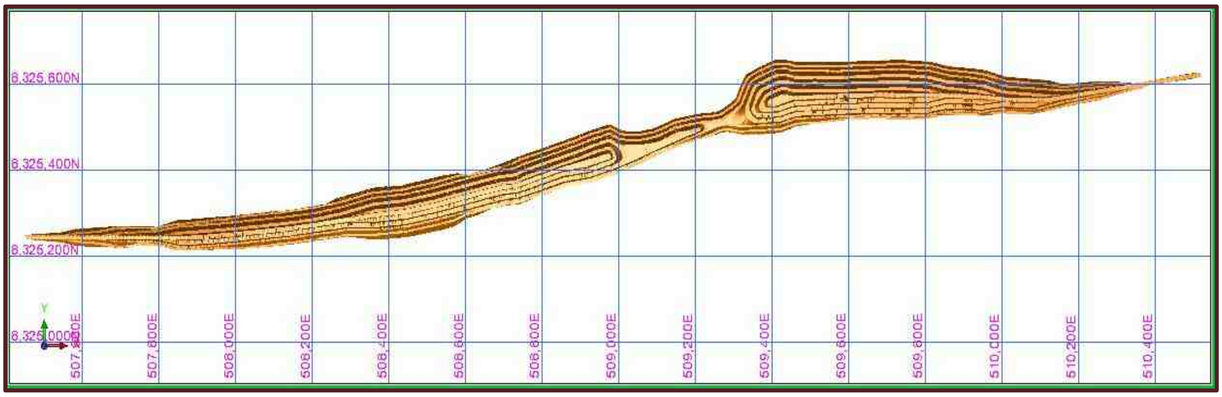

Figure 1.2: Pit Shell for 2020-2023 MMP.

The mine will continue to operate as an open cut operation using conventional drill and blast techniques. Ore will be loaded onto haulage trucks and taken to the ROM stockpile. The ore body targeted is high grade iron ore of greater than 60% Fe, which will be crushed and exported as DSO. The crushing process produces a lump (6 mm to 32 mm) product and a fines product (<6 mm) which will be stockpiled at the ROM for export. Lower grade ore (54% to 60%) will also be mined and blended with the DSO to meet contracted product grades (generally greater than 59% Fe).

1.2 Scope of Work

Following a review of the MMP, the Department of Primary Industry and Resources (DPIR) requested an updated AMD Management Plan (AMDMP). The most recent AMDMP lodged with the MMP only addressed the *Care and Maintenance* phase although it identifies the risks relevant to the site. Consequently the AMD Risk and Management Plan (Pendragon Environmental Solutions, 2013a) approved with the earlier MMP requires:

- Acknowledgement of the development and waste storage that has occurred on site to date.
- Provide comment on the quantities of PAF and associated risks proposed to be extracted during the plan period (effectively the next 12 months).
- Provide ongoing sampling and management requirements.
- Update the naming conventions in the report to acknowledge the new proponent (Nathan River Resources) and the new project name (Nathan River Project).
- Incorporate the comments from an independent peer review.
- Incorporate the comments by the Department of Environment and Energy.

1.3 Earlier Investigations and Assessments

Investigations and assessments undertaken to date with relevance to AMD and taken due cognisance of in compiling this document include:

Table 1.1: Earlier Investigations and Assessments.

Date	Entity	Investigation, Assessment, Comment
May 2012	WDR	Draft Environmental Impact Assessment (EIS).

		Including a report titled *Acid Metalliferous/Mine Drainage (AMD) and Management*, Roper Bar Project Area, Western Desert Resources Ltd, which documented a detailed investigation and assessment of the acid mine/metalliferous drainage and metal leaching potential of waste rocks and ore to ascertain the potential impacts to the local and wider environment. The salient findings of these investigations and assessments indicated that potential acid forming (PAF) materials are present and will require appropriate management to prevent impacts on the local and surrounding downstream receiving environments. To ensure that the environmental risks are inhibited, a preliminary risk assessment and framework for AMD management were also included in the EIS.
August 2012	WDR	Supplementary Environmental Impact Statement. Including a revised report titled *Acid Metalliferous/Mine Drainage (AMD) and Management*, Roper Bar Project Area, Western Desert Resources Ltd addressing comments made on the Draft EIS.
September 2012	NTEPA	Environmental Assessment Report and Recommendations
December 2012	DoE	Decision on Approval of Action (Approved with Conditions) received from the Federal Department of Sustainability, Environment, Water, Population and Communities. The conditions of approval by the NT Environmental Protection Agency (EPA) previously the Department of Natural Resources, Environment the Arts and Sport (NRETAS) and the Department of Sustainability Environment, Water, Population and Communities (SEWPAC, 2012) have also been considered in the current revision. Amongst others, the EPA indicated that: *to be substantiated with static and kinetic test results that indicate oxidised rock do offer real buffer (net acid consuming NAC potential). While it may be assumed that materials generating acid drainage can be mixed with acid consuming material in a waste rock dump to produce alkaline drainage, neither the proportion nor the amount of acid generating material, nor the degree of mixing required is known with any certainty and quantities of each material would need to be known. Blended NAG tests, column tests and field piles can be used to evaluate various mix ratios but generally a degree of conservatism is required to ensure an adequate excess of buffering is available (NRETAS 2012).* SEWPaC/DPIR indicated that to protect freshwater sawfish (*Pristis microdon*), the person taking the action must submit an Acid Mine Drainage Management Plan (AMDMP) for approval of the Minister which must include: **Condition 9:** a. Sampling and analysis procedures that will be employed to identify potential acid forming (PAF) materials. b. Design details and management strategies of proposed encapsulation beds, waste rock dumps, drainage systems, sediment traps, seepage diversion barriers, collection ponds and embankments. c. A strategy for the ongoing monitoring of PAF material, including threshold trigger levels and mitigation responses. **Condition 10:** Actions required under a) to c) must be consistent with the Managing Acid and Metalliferous Drainage Handbook (Australian Government, 2007) and any subsequent versions of this document. **Condition 11:** The person taking the action must ensure the AMDMP is reviewed by an independent technical reviewer to provide advice to the person taking the action on the development and review of the AMDMP. The person taking the action must nominate an independent technical reviewer. The independent technical reviewer must be approved by the Minister in writing. **Condition 12:** The person taking the action must ensure that the independent technical reviewer undertakes the following: a) Provide advice on the sampling and analysis procedures, design details and management strategies and the strategy for the ongoing management of PAF material.

		b) Provide advice on exceedance of trigger values and recommended changes to PAF material management practices, through the AMDMP, as required. **Condition 13:** The person taking the action must provide to the Minister copies of all advices and recommendations made by the independent technical reviewer and an explanation of how the advices and recommendations will be implemented or an explanation of why the person taking the action does not propose to implement certain recommendations. This information must be provided to the Minister when the AMDMP is submitted for approval. **Condition 14:** The AMDMP must be submitted for approval by the Minister at least 60 days prior to the start of mining, unless otherwise approved in writing by the Minister. **Condition 15:** Mining must not start until the AMDMP has been approved by the Minister. The approved AMDMP must be implemented. **Condition 16:** For the ongoing protection of freshwater sawfish (Pristis microdon), the AMDMP must be reviewed annually from the date of first approval of the AMDMP (until two years following the closure of Area F East Pit 3) by the independent technical reviewer, to enable continuous improvement and adaptive management of PAF material management. From two years following the closure of Area F East Pit 3, the AMDMP must be reviewed by the independent technical reviewer once every three years for the remaining life of the project. The person taking the action must provide to the Minister, a copy of all advice and recommendations made by the independent technical reviewer and an explanation of how the advice and recommendations will be implemented or an explanation of why the person taking the action does not propose to implement certain recommendations. If the independent technical reviewer recommends that the approved AMDMP be varied, then the approved AMDMP must be varied in accordance with condition 5.
May 2013	WDR	Submission of Mining Management Plan. Including a report titled *AMD Risk Assessment and Management*, Western Desert Resources which also documented the results of preliminary kinetic testing: The initial investigations and assessments, coupled with commitments made during the approvals process, indicated the need for further assessment of materials falling in the uncertain category and PAF mine spoils to ascertain whether these materials will produce net acidity over the long-term. As a consequence WDR established six columns for leach (kinetic) testing to determine and assess the long-term reactivity of sulphides and buffering capacities of mine spoils including metal loading and toxicities. Preliminary observations after 17 weeks of testing indicated that: ▪ High pH and large sulphate concentrations indicated rapid activity of buffering minerals. The onset of circumneutral pH (normally >6.0) in the leachates indicates the presence and steady activity of carbonates (and silicates) with acid neutralizing capacities in excess of acid produced by the oxidation of sulfides. ▪ The subsequent short term behaviour of pH and solute loadings are indicative of slow sulfide reactions and dominance by buffering capacities. The pyrite oxidation rates calculated for exposed surface areas averaged a slow 2.25E-11mol/m^2/s. ▪ The pH and solute loading patterns have not yet shown the peak of the AMD zone. The time lag when acid or alkaline conditions sets in and commences to control the weathering environment was also not detected. ▪ The results and observations to date are inconclusive and kinetic testing should continue until clear patterns of acid and/or base production are confirmed. ▪ The Mine Management Plan (MMP) should consider and incorporate these preliminary observations and continue to employ these tests as tools of the AMD Risk Assessment and Management Plan and their continual reviews. SRK commented in a document titled *Roper Bar Independent Technical Review,* Report Prepared for Commonwealth Bank of Australia, SRK Consulting (Australasia) Pty Ltd, June 2013, Section 8.1.5 Waste Dumps and AMD Potential. Their comments, where relevant, were incorporated in a subsequent revision of the AMDMP.

June 2013	Golders	The salient findings and key recommendations of the independent technical review of the 2013 AMDMP and associated documentation, including risk assessments and chapters of the EIS. A detailed response was submitted by Pendragon Environmental Solutions in July 2013. The AMDMP was considered sufficiently comprehensive for the scale of operations and could readily inform the Mine Closure Plan. The response indicated that material characterisation and kinetic testing was to be expanded continually as part of grade control and the results fed into the mine block model to inform further sampling and analysis.
September 2014	WDR	WDR placed into receivership: production ceased and care and maintenance phase entered.
November 2015	WDR	Updated Care and Maintenance Plan lodged with DPIR. Including a report prepared by GHD titled *Roper Bar Iron Ore Project, Acid and Metalliferous Drainage Management Plan*, Care and Maintenance – Mining Management Plan, November, 2015. This document takes due cognisance of the contents of this latest AMDMP for Care and Maintenance.
November 2019	Amanzi Consulting	Independent Peer Review and Table 1 Checklist (Appendix B). Appendix B also includes a response indicating where and how the issues/gaps raised were addressed in this document.

2. AMD Management

The management option detailed in this document is designed to promote best practice and continuous awareness and environmental improvement by means of a life-cycle approach towards AMD management and detailed risk assessments and is consistent with the following documents:

- *Acid Metalliferous/Mine Drainage (AMD) and Management*, Roper Bar Project Area Western Desert Resources Ltd, EcOz, 2012.
- *AMD Risk Assessment and Management*, Western Desert Resources Limited, Pendragon Environmental Solutions, 2013a.
- The Independent Technical Review, Golders, 2013 included in Appendix B of this document.
- *Acid and Metalliferous Drainage Management Plan, Care and Maintenance - Mining Management Plan*, Roper Bar Iron Ore Project, Western Desert Resources Limited, GHD, 2015.

The framework articulated in these documents aims to focus on early identification of AMD risk to focus the effort on prevention or minimisation rather than control or treatment. It also allows for frequent reviews and continual improvement. This AMDMP is to be included in the Mine Management Plan 2020-2023.

2.1 Pre-Mining, Mining and Care and Maintenance AMD Management

Pre-mining investigative activities included AMD investigations and assessments (EcOz, 2012) which indicated that materials with a potential to produce acidity (PAF) are present at the site. Because of the need to classify materials as either net acidic or alkaline, column leach (kinetic) testing was implemented (Pendragon Environmental Solutions, 2013b). This latter document included a detailed risk assessment and management plan for operations. A subsequent AMDMP (GHD, 2015) was prepared for Care and Maintenance. Whilst these documents were considered in preparing this AMDMP, they are not included.

Investigations committed to in the above during the EIS process included pre-mining ore grade control including field measurements complemented where needed with laboratory analytical investigations. This phase of the mine spoil characterisation will fundamentally assist with the quantification of PAF/NAF materials and therefore with the refinement of the block models.

2.2 AMD Risk Assessment

Ecological and human health risk assessments were undertaken (EcOz, 2012; Pendragon Environmental Solutions, 2013 and GHD, 2015) to determine the risks associated with the AMD materials at the site taking due cognisance of:

- PAF materials identified during various geochemical assessments.
- Metals leaching potential of the different materials.
- The MMP and schedule.
- Baseline environment and sensitive receptors.

The AMD risk assessments are *source focused* and consequently not an exhaustive assessment and study of downstream impacts; they were completed to provide a high level understanding of AMD risk using a source-pathway-receptor model (INAP, 2009). The general approach to the risk assessment followed standards and leading practice guidelines including:

- AS/NZS 4360:2004 Risk Management.
- AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines.
- Managing Acid and Metalliferous Drainage (DITR, 2007).
- The Global Acid Rock Drainage Guide (INAP, 2009).

The risk assessment was informed by detailed geochemical assessments and the MMP and schedule and also acted as an information gap analysis (GHD, 2015). The gap analysis indicated that the laboratory acid base accounting and metals leaching data sets are both too small to be statistically significant. To improve confidence in these data sets, additional sampling and analysis would be required to inform AMD risk and management strategies in subsequent revisions of this document. Consequently, laboratory XRF data was used to inform the AMD risk assessment. This data set indicated that (GHD, 2015):

- *There is a relatively small volume of PAF material present on site and that forward risk can be readily managed and/or mitigated.*
- *There were no elevated metals concentrations present in the three main geological units on site relative to the median crustal abundance of those same metals. However, some minor metals and contradictory sulfate leaching were evident requiring additional analysis.*

The AMD risk assessments to date indicate that with appropriate design and operational control measures, the residual AMD risk is medium at worst and manageable with effective controls. Any residual risk would be monitored during implementation of the AMDMP to confirm that the design and operational control measures are effective.

Table 2.1: AMD Risk Assessment and Mitigation Measures.

Aspect	Impact	Design Control Measure	Operational Management Measure
PAF material causing uncontrolled AMD Acid, Metalliferous and Saline Drainage	Downstream water quality (low pH, elevated sulfate and metals) impacts on ecological values. Reputational Risk.	Clay lined PAF cells within WRDs. Selective materials handling and placement. Separate, clean, dirty and contaminated water drainage systems. Surface water management basins.	AMD Management Plan Water Management Plan Mine schedule and geochemical modelling. Controlled and managed site drainage and release.
WRD and ROM pads leaching metals	Downstream water quality (elevated metals) impacts on ecological values.	Compacted WRD and ROM pad base. Use of NAF material.	AMD Management Plan. Water Management Plan. Controlled and managed site drainage and release. Ongoing cover trials during DSO.
WRD design and cover material	Rainfall ingress into WRDs resulting in downstream water quality (low pH, elevated sulfate and metals) impacts on ecological values.	Use of NAF material. Determine a suitable cover design.	
LGO, DSO, BDSO, DMSO and SIDO stockpiles leaching AMD and elevated waste mineralisation	Downstream water quality impacts.	Compacted ROM pad base. Separate clean, dirty and contaminated water systems. Controlled and managed site drainage and release.	AMD Management Plan. Waste Discharge Licence.

Aspect	Impact	Design Control Measure	Operational Management Measure
Dispersive waste management	Rehabilitation issues including tunnel erosion and landform failure.	Selective cap material. Ameliorate/amend material to increase calcium content.	Rehabilitation Management Plan. Inspection and monitoring.
In-pit exposed PAF material causing poor pit water quality post closure	Groundwater leaching AMD into pit becoming either an AMD sink or source.	Future Beneficiated Ore Project - mine out PAF area.	AMD Management Plan.

2.3 AMD Management Plan

The AMDMP detailed below supports the 2020-2023 Mine Plan and was structured in accordance with the conditions for approval and Sections 4, 6, 7 and 9 and Appendix 1 (Commonwealth of Australia, 2016) and the *Technical Review: AMDMP for the Roper Bar Mine, Northern Territory* (Amanzi Consulting, 2019).

Table 2.2: AMD Management 2020-2023.

Responsibility and Accountability	Operator:	NRR Mining Pty Ltd (619 218 665) Key Contact Person: Simon Peat Street and Postal Address: Unit 18, 109 Holt Street, Eagle Farm, QLD 4009 Phone: +61 418 124 024 e-mail: simon.peat@britmargroup.net
	Assisted by:	Pendragon Environmental Solutions
Objective, Purpose and Operational Policy	To achieve best practice AMD management at the Nathan River Project. The principle objective is to manage AMD risk resulting from oxidising sulphidic mine waste such that local and downstream environmental values are not at risk. To ensure appropriate systems, processes and procedures are in place to adequately and effectively manage the risk of AMD being generated throughout the 2020-2023 mining plan. To provide for the classification of waste rocks and validation and monitoring procedures for the effective handling and long term storage of waste rock. Materials are not to be disturbed, nor excavated, and/or are not to be placed without facilities with adequate capacities. Maintain disturbances within the limits required for construction. All construction/site workers will be made aware of this document to ensure that acid generating materials are handled and managed effectively.	
9a. Sampling and Analysis Procedures employed to identify potential acid forming (PAF) materials.		
4.2 Sampling for Identification and Characterisation. **4.2.1 Overview**	Sampling for identification and material characterisation were undertaken between 2012 and 2014 (EcOz, 2012; PES, 2013a and WDR, 2014). Subsequent analysis included assessments when the mine was placed in administration but did not include sampling (GHD, 2015) other than extending the database for kinetic leach column testing from 17 weeks (PES, 2013b) to 76 weeks (GHD, 2015). No further sampling and analysis, including monitoring of the kinetic leach columns were undertaken after May 2014. The primary aim was to define the main lithologies and geological units and mine ore and waste materials based on Fe content. Material with an iron content <30% is classified as waste and is transported directly to the WRD's where it is managed according to their PAF, NAF, UC or AC sub-classifications.	

	Multiple test methods with increasingly detailed sampling and analysis facilitated materials characterisation with geochemical classification of mine materials into PAF, NAF and UC categories and assessing risk using a Source-Pathway-Receptor model (PES, 2013a and GHD, 2015).
	
	Material characterisation was undertaken:
	
	▪ to meet the conditions for approval of the Environmental Impact Statement (EIS) by the NT EPA; and
	▪ subsequently, to meet the requirements of the EPBC Act conditions for approval;
	
	including:
	
	▪ Sampling and analysis to identify PAF materials in accordance with industry best practice and statutory guidelines.
	▪ Develop management strategies and designs for WRD's with containment/encapsulation cells and drainage systems comprising diversion/containment bunds/channels, embankments, sediment traps, seepage diversion barriers and collection ponds.
	▪ A strategy for the ongoing management and monitoring of PAF material, including threshold trigger levels and mitigation responses.
	
	by employing:
	
	▪ Static geochemical laboratory testing on (PES, 2013a):
	  o 24,457 (12,007 in pit) laboratory XRF measurements (5,433 of the KYM, 14,380 of the SIM and 4,644 of the MSM) of Total S (%), CaO (%) and MgO (%) from 3,125 drill holes;
	  o 204 (60 in pit) ABA/NAG Total S from 47 drill holes;
	  o 17 samples by WDR in 2014 as a quality assurance check/validation of the NAPP data set and subsequent classification of the WST unit (the bulk of which was from the upper weathered material at Roper Bar);
	
	  sufficient to populate a geological block model with reliable distribution of NAPP data on the ore and the mine waste streams including ore, overburden and discards.
	▪ Kinetic leach column testing on representative samples for key lithologies and waste materials specifically those identified as PAF or UC.
	
	Geochemical testing included:
	
	▪ Mineralogical assessments by XRD, XRF, SEM and EDS.
	▪ Static (ABA) testing, Maximum Potential Acidity (MPA), Net Potential Ratio (NPR) and Net Acid Production Potential (NAPP).
	▪ Metal assessments using the Geochemical Abundance Index (GAI) and laboratory Australian Standard Leaching Procedure (ASLP).
	▪ Kinetic testing: column leach construction, sampling and analyses with laboratory testing and ASLP.
	
	Sufficient sampling and analysis have been undertaken to establish a block model and inform future sampling protocols, analytical needs and ongoing test work, to confirm findings and direct adjustments to risk assessments and management plans (Amanzi, 2019).
	
	Despite the NAF classification for all units in the kinetic leach columns, small pockets of PAF were confirmed by geochemical block modelling (GHD, 2015). Materials on site will be managed using NAF < 0.3% Total S < PAF as the classification tool in the site assessment procedure (Appendix C). Using Total Sulfur (the acid forming nature of the material) as a classification tool is a conservative approach. This approach excludes consideration of acid neutralising minerals including CaO and MgO.
	
	Additional validation sampling and laboratory geochemical analytical results in future will inform the refinement of this approach minimizing expected PAF volumes by inclusion of the effective acid neutralising or buffering capacity of certain minerals i.e. future classification will be based on static NAPP and acid buffering characteristics curves (ABCC) rather than simply using Total Sulfur values.

	Therefore, the PAF volumes shown in Section 4.4 below are inherently conservative and would likely represent an upper estimate.
4.2.2 In-place mine materials	Sampling and analysis prior to mining enabled *in situ* material identification and characterisation (EcOz, 2012 and PES 2013a). Two hundred and four samples were obtained from fifty-eight exploration boreholes in various geological horizons and rock types present at the mine including: ▪ Area E: East and South Pits. ▪ Area F: East Pits 1, 2 and 3 and the West Pit. Samples were obtained from the main lithologies including sandstones and oolitic sandstone, siltstones and clays from the main geological units i.e. the Kyalla Siltstone Member (KYM), the Moroak Sandstone Member (MSM) and the Sherwin Iron Member (SIM). Further sampling and analysis for static testing to be undertaken during the 2020-2023 Mine Plan include 75, 140 and 27 samples from the KYM, MSM and SIM respectively (refer Section 4.9 below).
4.2.3 Existing exposed mine materials	Other than the some 135,000t of DSO that were blasted but remained *in situ,* and which is currently flooded, there are no PAF materials exposed (personal communication Gavin Otto, NRR Geology/Environment Manager).
4.3 Static Geochemical Tests **4.3.1 Field measurements** **4.3.2 Mineralogical analysis** **4.3.3 Elemental composition** **4.3.4 Acid base accounting** **4.3.5 Net acid generation test** **4.3.6 Sulfur and carbon speciation** **4.3.7 Sample classification**	**Field measurements** included pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO) and temperature (T) of the column leachates. **Mineralogical Analysis (EcOz, 2012 and PES, 2013a)** ▪ Fifty-six samples were analysed using X-ray powder diffraction (XRD). ▪ Forty-six samples representing the principle waste rock streams were analysed by Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectrometer Analysis (SEM-EDS) techniques. ▪ Sulfur assessment by XRF analysis of fifty one laboratory analysed samples. **Elemental Composition (EcOz, 2012 and PES, 2013a):** ▪ Laboratory X-Ray Fluorescence (XRF) of 24,457 samples for Total S%, CaO and MgO; other analytes included: Al_2O_3, Fe, Mn, Mo, P, SiO_2, TiO_2 and K_2O. ▪ Hydrochemical leach testing of eighty-five samples employing ASLP; the results were plotted on Piper diagrams to classify leachates: According to their hardness (as $CaCO_3$), computed from calcium and magnesium concentrations, the majority of leachates classify as being very soft with only five samples falling in the moderately soft to very hard categories. Dominance of very soft leachates is indicative of low calcium and magnesium concentrations having a low buffering capacity with the potential to influence water treatment and management processes. Most of the samples from E East and South produced sodium-potassium-bicarbonate type leachates and a significant number of samples from F-East Pits 2 and 3 produced sodium-potassium-sulfate-chloride type leachates. A small number of samples from F West and F East Pit 1 also produced sodium-potassium-bicarbonate type leachates. About 40% of samples produced leachates with no dominant anions or cations. **Acid Base Accounting and NAG testing (EcOz, 2012 and PES, 2013a):** To characterise the materials at the site, including the materials that will make up the WRD, two hundred and four samples were submitted for laboratory ABA and NAG testing. One hundred and seventy-five of these samples came from the KYM, MSM and SIM units within the mine disturbance area. A standard suite of analyses, using prescribed methods by an accredited laboratory, was used to determine the acid base chemistry for all waste materials: ▪ pH and EC of paste solutions.

- Oxidation pH.
- Total S and sulphate sulfur.
- Acid Neutralising Capacity (ANC), carbonate alkalinity (as $CaCO_3$) and Net Acid Generation (NAG).

From the laboratory analytical data, Maximum Potential Acidity (MPA), Net Acid Producing Potential (NAPP) and the Acid Potential Ratio (APR) values were calculated.

In summary, geochemical static test work reporting included:

- Descriptions of methods used in the sampling and analysis.
- Records of the initial results of characterisation of *in-situ* materials.
- Records of the leachate chemistry from the waste materials.
- Assessment of the geological sequence to determine PAF, NAF or UC by lithology.
- Identification and characterisation of the potential sources of AMD in the East and West Pit WRD's
- A preliminary mine waste balance and a mine waste management option including the placement of PAF material within containment cells in the WRD's.
- Document a risk assessment process and provide a risk assessment for the management of mine wastes.

Sample Classification (PES, 2013a and GHD, 2015)

Material types are classified according to iron content:

- Mine wastes (WST) are materials with <30% Fe content subdivided into geological units KYM, SIM, MSM and sub-units of fresh and weathered (oxidised).
- Ore types are defined by Fe content >30%: Direct Shipping Ore (DSO) >60%, Blended Direct Shipping Ore (BDSO) 54-60%, Dense Media Separation Ore (DMSO) 45-54%, Siderite Ore (SIDOO) 30-54% and LOI >10% and Low Grade Ore (LGO) both fresh and weathered.

Materials are also characterised as (Commonwealth of Australia, 2016 and other relevant AMD standards and guidelines):

- Non Acid Forming (NAF).
- Potentially Acid Forming (PAF).
- Uncertain (UC, material that cannot be classified definitively as PAF or NAF).
- Acid consuming (AC).

The AMD characteristics of the different lithologies, including weathered (oxidised) and fresh, are classified according to Total Sulfur content: Low Sulfur <0.3% and High Sulfur >0.3%. Using Total S (%) is a conservative approach as sulfate sulfur, which may have neutralising sulfates, is excluded.

Calculated parameters for material characterisation include:

- 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 oxygen to $Fe(OH)_3$ and H_2SO_4.
- The Net Acid Producing Potential (NAPP) values (in kgH_2SO_4/t) were calculated from the MPA and Acid Neutralisation Capacity (ANC) values: NAPP = MPA - ANC.
- The Acid Potential Ratios (APR) were calculated from the relationship ANC/MPA.

  The more conservative 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. A material is likely potential to produce acidity if $1 \leq APR \leq 2$; 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 concentration.

	The ABA static testing program (EcOz, 2012) yielded geochemical characterisation, as a % of all samples tested: NAF 52%, PAF 34% and Uncertain 14%. These might be skewed due to the preference at the time to target the materials most likely to generate acidity. Using NAPP calculations indicated that the volume of PAF materials are small and that volumes can be estimated using the Total S (%) grade cut off of 0.3% (GHD, 2015) which is considered conservative as it excludes CaO and MgO minerals with a neutralising capacity.
4.4 AMD Block Modelling and Materials Scheduling	WDR populated a block model for the E East Pit and combined F-Pit (F East and F West 1 to 4) (Appendix D) with their XRF dataset. They included NAG test data (EcOz, 2012) and were undertaking additional validation sampling and assessment to supplement the ABA/NAG dataset (PES, 2013a) at the time the operation was placed into administration. The data set comprised (locations are included in Appendix D): ▪ 24,457 (12,007 in pit) laboratory XRF measurements (5,433 of the KYM, 14,380 of the SIM and 4,644 of the MSM) of Total S (%), CaO (%) and MgO (%) from 3,125 drill holes. ▪ 204 (60 in pit) ABA/NAG Total S from 47 drill holes (PES, 2013a). No sampling and analysis was done after the mine was placed in administration (GHD, 2019). Total Sulfur values <0.3%S or 10kgH_2SO_4/t are considered UC (DITR, 2007) that will be subject to further sampling and analysis in terms of this plan. The block model, currently based on coarse sampling and a conservative 0.25% Total S (PAF) cut-off, will be reviewed from time to time as required and upon further sampling and analysis, including lithological modelling with closer-spaced pre-production sampling, to delineate AMD risk within the pit shell and to determine appropriate management of mine waste. There is good spatial correlation between the geochemical model, the laboratory XRF dataset and the geological block models. With regard to data set correlation there is a very good correlation between the ABA and laboratory XRF Total S data sets. The laboratory (ABA) derived NAPP data shows a significantly lower NAPP value in comparison to the estimated assay NAPP value (laboratory XRF) indicating that the latter does not consider all neutralising minerals unlike the laboratory ABA titration method (GHD, 2015). The spatial variability assessment indicated that sulphur grade has been adequately represented by the sample density of the laboratory XRF data along approximate 100m section lines at E East and on 150m section lines or better at F East and F West well within the limits shown in the correlogram (GHD, 2015). The order of magnitude sampling assessment showed that an adequate number of geochemical samples had been obtained in the laboratory XRF dataset to undertake a preliminary geochemical assessment; however, further laboratory testing is required to increase ABA data, including metals, to ensure the AMD risk assessment can be improved over the life of mine at Roper Bar (GHD, 2015). **Materials Schedule** The proposed mining activities for 2020-2023 will focus on the existing Area F-East mining pits where the ore body has been exposed during the previous mining operation. The initial pit design will remain within the current footprint of the existing pit limits and contains approximately 2.5 Mt of ore (Fe > 45%), 1.5 Mt of low grade ore (Fe 30% – 45%), 190 Kt of PAF material and 9.5 Mt of waste rock (NAF). Waste rock will be stored in existing F-East waste rock dumps (WRD) and potential acid forming waste (PAF) will be stored in the existing PAF storage area on the F-East WRD (Appendix A). F-East Pit 1 (FE1) and F-East Pit 2 (FE2) contains approximately 1.2 Mt of material which has been previously blasted and remains *in-situ*. This blasted material contains 225Kt ore and approximately 9Kt of PAF material and the remaining is NAF waste. The blasted material will be the initial focus of the mining operations. Ore, LGO, NAF and PAF wastes will also be concurrently mined and extracted. Material quantities to be mined within the current pit design for Area F East between 2021 and 2023 are:

Type of Material	Approximate Quantity (kilo-tonnes)	% of Total
Ore	2,490	18%
PAF Waste	190	1%
NAF Waste	10,940	80%
Total:	**13,620**	**100%**

The monthly mining schedule (built for financial modelling) for the Area F East pits within the current pit design is shown below (note that LGO and PAF materials are included within waste and has not been scheduled separately).

Month	Ore	Waste	Total
	(kt)		
Apr-20	32	324	356
May-20	83	524	607
Jun-20	76	560	636
Jul-20	68	531	599
Aug-20	83	671	754
Sep-20	70	595	665
Oct-20	81	545	626
Nov-20	85	519	604
Dec-20	81	437	518
Jan-21	83	525	608
Feb-21	86	426	512
Mar-21	100	597	697
Apr-21	88	426	514
May-21	93	402	495
Jun-21	78	267	345
Jul-21	87	321	408
Aug-21	75	205	280
Sep-21	57	160	217
Oct-21	62	329	391
Nov-21	89	239	328
Dec-21	57	305	362
Jan-22	58	270	328
Feb-22	64	335	399
Mar-22	50	227	277
Apr-22	93	272	365
May-22	95	210	305
Jun-22	90	184	274
Jul-22	93	151	244
Aug-22	40	128	168
Sep-22	41	118	159
Oct-22	42	94	136
Nov-22	42	69	111
Dec-22	100	118	218
Jan-23	55	43	98
Feb-23	13	5	18
Total	**2,490**	**11,132**	**13,622**

4.5 Geochemical Kinetic Column Leach Testing	Whereas static tests provide geochemical information on the existing composition of a sample, kinetic tests provide longer term data which incorporate the effects of secondary minerals (Ca, Mg, Fe, and Mn hydr[oxides]) which may impact the quality of surface and ground water drainage (Pendragon Environmental Solutions, 2013b). Consequently, kinetic testing was implemented, following a risk assessment (Ecoz, 2012 and PES, 2013a), to inform WRD designs and the management of PAF materials during mining operations. Static testing indicated that PAF materials predominantly occur below 30m depth. Six columns, containing primarily weathered and fresh KYM from pit samples and drill cuttings, were constructed as two sets of columns, with a mixture of PAF and NAF materials, one set representing low sulfide spoils and the other set high sulfide spoils concentrations, were constructed to assess mine waste materials (PES, 2013b). The subsequent analysis of sampling data after week 17 (PES, 2013b) indicated that: ▪ Columns 1 and 2 were confirmed as PAF. ▪ Column 5 was UC. ▪ Column 3 confirmed as NAF. ▪ Columns 4 and 6 were found to be UC. ▪ The leachate qualities observed are indicative of spoil materials that have been weathered naturally. ▪ High pH and large sulfate concentrations indicate fast reaction of buffering minerals and the release of diluted accumulated acidity and readily available sulfate salts. The circumneutral pH (normally >6.0) in the leachates indicates the presence and steady activity of carbonates (and silicates) with acid neutralizing capacities in excess of the acid produced by sulfide oxidation. ▪ The subsequent short term behaviour of pH and solute loadings are indicative of slow sulfide reactions and dominance by buffering capacities. The pyrite oxidation rates averaged a rather slow 2.25E-11mol/m^2/s. ▪ The peak of the AMD zone at which high sulfide oxidation and acid generation exceed or are lower than acid neutralising capacities has not been observed. The time lag when acid or alkaline conditions sets in and commences to control the weathering environment was also not detected. ▪ The results and observations between 22 November 2012 and 22 March 2013 (first 17 weeks) were inconclusive and it was recommended that kinetic testing should continue until clear patterns of acid and/or base production are confirmed. The kinetic geochemical column leach data was updated to May 2014 and re-interpreted (GHD, 2015); the salient findings were: ▪ Kinetic testing assisted with validating the predictive work completed using the laboratory XRF and static ABA datasets and understanding the rate of any acid forming and neutralising reactions, and therefore, the AMD temporal risk. ▪ The data indicated that all six columns returned circumneutral pH values and EC's that exceed the 99% ANZECC trigger values indicating the potential for saline drainage from the KYM unit. Slightly elevated Al, Fe, and Mn concentrations relative to the 99% ANZECC trigger values may indicate a potential stored acidity pool. Whilst Cd, Cr, Cu, Pb, Ni and Zn have limited mobility, the results will be used as indicative of the potential drainage water quality. ▪ Column 1 (fresh KYM material; PAF): the materials classify as PAF(LC) with a NAPP value of 5.48kgH_2SO_4/t. Although pyritic sulfur was present (1% pyrite), the relationship between total alkalinity, acidity and pH indicated that the inherent neutralizing capacity (ANC) was effective for at least the first 76 weeks of testing. ▪ Column 2 (fresh and weathered KYM material; PAF): the materials also classify as PAF(LC), with a NAPP value of 0.31kgH_2SO_4/t. Although pyritic sulfur was present (4% pyrite), the relationship between total alkalinity, acidity and pH indicated that the neutralizing capacity was effective in neutralising acid for at least the first 76 weeks of testing.

	▪ Column 3 (weathered KYM material; NAF): the materials classify as NAF with a NAPP value of -7.94kgH_2SO_4/t. Pyritic sulfur was not identified. The relationship between total alkalinity, acidity and pH indicated that the neutralizing capacity (ANC) was effective in negating acid generation for the 76 weeks of testing. ▪ Column 4 (fresh and weathered KYA material; NAF): the materials classify as NAF with a NAPP value of -11.03kgH_2SO_4/t. Although pyritic sulfur was identified as being present by SEM, the relationship between total alkalinity, acidity and pH indicated that the inherent neutralizing capacity was effective for the 76 weeks of testing. ▪ Column 5 (fresh KYA material; NAF): despite being selected as an elevated sulfur column, the materials classify as NAF with a NAPP value of -5.54kgH_2SO_4/t. Although pyritic sulfur was identified by SEM as being present, the relationship between total alkalinity, acidity and pH indicated that the inherent neutralizing capacity was effective for the 76 weeks of testing. ▪ Column 6 (fresh KYA material; NAF): the materials classify as NAF with a NAPP value of -6.13kgH_2SO_4/t. Although pyritic sulfur was identified by SEM as present, the relationship between total alkalinity, acidity and pH indicated that the inherent neutralizing capacity was effective for the 76 weeks of testing. Monitoring of the columns ceased when the mine was placed in administration. The columns have been damaged by fire since such that NRR has committed to installing new columns once mining recommences.
4.5.2 Oxygen consumption tests	To date laboratory oxygen consumption has not been undertaken during any of the earlier investigations. Kinetic column leach testing will recommence when mining under this plan commences. Whilst oxygen consumption tests have several advantages (Schmieder *et.al*., 2010), they do not account for the influences of parameters such as activity of bacteria, temperatures, humidity, pressure and time lag due to saturation of oxygen at micro-environment levels. Some of these parameters, are well known and explained in literature about conventional kinetic testing, and accordingly, the oxygen consumption test, particularly the role of water content in the system, remains unverified as an approach to determine the Sulfide Oxidation Rate (SOR). Field kinetic testing aids with assessing the relevant parameters as indicated above. It also allows a continuous assessment of leachate by flushing production of acidity and other key hydrogeochemical parameters and to control the water content of the system.
4.5.3 Oxygen penetration tests	These tests, used in tailings storage facilities (TSF's), will not be undertaken; there will be no TSF at the mine.
Scaling-up of laboratory test results **4.6.1 Pilot-scale field tests** **4.6.2 Large to full scale field tests**	Not undertaken and/or required yet as geochemical testing indicated that small volumes of PAF can be contained in cells within the waste rock dump (WRD). The WRD will be monitored: visual observations for leachates and or precipitation of salts coupled with water quality monitoring in the open pits, sedimentation ponds, streams and monitoring bores (refer Section 9 below).
Estimating and modelling pollutant generation and release rates **4.7.1 Overview** **4.7.2 AMD prediction using empirical test results**	Laboratory ASLP metal leaching and Kinetic Leach Column testing were undertaken between 2012 and 2014 and further testing will be undertaken during the 2020-2023 Mine Plan which will form the basis for AMD predictions using the Conceptual Site Model and empirical methodologies. Computer modelling is not warranted given the scale of mining and low risk of AMD. During kinetic leach testing (PES, 2013b), the acidity load during the first flush event (total acidity as compared to total alkalinity) were relatively high in Columns 1 and 5, whilst in the others alkalinities were dominant. The highest acidity concentrations occurred in Columns 1 and 5 and the lowest in Columns 2 and 3. Although alkalinity concentrations remained dominant, with an increasing trend in time, acidity in Columns 4 and 5 slightly increased in week 17:

4.7.3 AMD prediction using computer models

Date	Acidity as $CaCO_3$ (mg/L)					
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
22/11/2012	32	4	7	6	24	8
18/12/2012	22	10	6	6	10	10
31/01/2013	15	8	6	9	13	7
13/03/2013	14	8	9	20	18	15
30/04/2013	10	5	6	19	12	11

Alkalinity-acidity balance and sulfate concentrations indicated that sulfides in contrast to the buffering materials of the samples are slowly reacting (PES, 2013b). Elevated pH due to constant alkaline material dissolution is unfavourable for the oxidation of FeS_2 as this reduces the catalytic effect of bacteria and precipitates iron oxides which partially coats the available sulfide surfaces and reduce the rates of sulfide oxidation and acid generation.

9b. Design details and management strategies of proposed encapsulation beds, waste rock dumps, drainage systems, sediment traps, seepage diversion barriers, collection ponds and embankments.

6.1 Management of WRD's to minimise AMD

6.1.1 General considerations

6.1.2 Conventional end-dumped WRDs

6.1.3 Oxidation rate and lag time to production of AMD

6.1.4 Construction methods for WRDs to minimise AMD production

6.1.5 Minimising self-heating and AMD potential

6.1.6 Minimising AMD risk at sites dominated by PAF waste rock

An estimated 53,000t of PAF mined during active operations in 2014 was placed in the PAF Cell constructed and operated by Theiss for WDR (Appendix A[1]) at the western end of the Area F East WRD. The open PAF Cell was later covered with 1.2 m thick NAF material followed by a rock and soil layer some 0.5 m thick that was track rolled and subsequently shaped for drainage by the Administrators in 2014/2015 prior to the 2014-2015 wet season. The materials stored have been classified as low risk (GHD, 2015).

When sulfide oxidation rates (SORs) were compared in relation to time (days), the rate of sulfate production substantially declined for all columns (PES, 2013b). A preliminary calculated pyrite oxidation rate averaged 2.25E-11mol/m^2/s ranging from 5.88E-12mol/m^2/s to 7.26E-11mol/m^2/s. The lowest SOR was observed in Column 2 and the highest in Column 3 (PES, 2013b). Even though the SORs appear to indicate influences by the quality of leaching solutions, column water content, irrigation rate and availability of oxygen, these are comparative to SORs obtained by different researchers at various mining sites within Australia and overseas (Bennett *et. al.,* 2000).

The current PAF cell has a remaining capacity of approximately 50,000bcm or 135,000t which will be sufficient for the 2020-2023 Mining Plan. There are no other materials or storage areas of PAF elsewhere on the site. Stockpiling of the LGO will continue during mining; NRR will undertake test work and feasibility studies for future beneficiation of the low grade material. To provide greater certainty of the amount of PAF waste requiring management, drilling and sampling will be undertaken on 50m lines during grade control. Sampling and analysis will be undertaken in accordance with Section 9 below.

Near the end of operations (just prior to entering Administration), mine geologists identified two horizons within the Maroak Sandstone (waste on the northern side of the Area F East pits) that most likely contributed towards much of the PAF material. This indicates that if the PAF material is mainly hosted within defined and mappable beds of the Maroak Sandstone, the PAF material can be targeted and delineated by drilling on 50m lines during the grade control drilling program. The current procedure of floor waste rock sampling and sampling of vertical blast holes will be assessed with the results of the waste rock drilling for PAF material determination. The 1m sampling of the proposed waste rock drilling will provide tighter spatial constraints than is possible with the vertical blast hole sampling. At present, the PAF waste material on the northern side of the resource is poorly defined in the block model due to the paucity of drilling in that area.

NRR recognises and is aware that prevention will help avoiding many of the long-term issues and difficulties faced at mine rehabilitation and closure and that planning for closure is a fundamental component of mine planning; therefore, identifying any PAF material is essential to facilitate effective and successful long term management. Consequently NRR will continue to develop appropriate AMD design and operational controls to minimise forward closure risks.

[1] To date only the western PAF Cell has been constructed by Theiss for WDR in 2014. The eastern cell will be constructed in future and/or in the unlikely event that additional storage is required for mining under this AMDMP.

	The overall AMD strategy for the 2020-2023 MMP was considered within the context of a future planned beneficiated ore project designed to maximise asset value. Consequently the overall waste rock management strategy over the life of the mine includes open pit rehabilitation including progressive future pit backfilling (complete or partial). The AMD management strategy to date has been based on exploratory drilling which identified the ore bodies extending to depths beyond that currently mined in certain areas. Future AMD management strategies will be based on grade control and targeted drilling of material zones identified as containing PAF. Mining activities to date produced (and will produce in future) mineral waste streams classified as either: ▪ weathered (oxidised) overburden comprising the Kyalla Siltstone Member (KYM), the Moroak Sandstone Member (MSM) and a small amount of Sherwin Iron Formation (SIM) that grades <30% Fe (SIM); and/or ▪ weathered and/or unweathered (unoxidised) fresh rock KYM, SIM and MSM surrounding the ore body that require removal during cutbacks to access the SIM ore. A portion of the mineral waste stream was re-used during earlier operations for: ▪ The weathered (oxidised) KYM to construct the base of the waste rock dumps (WRDs) and ROM pad. ▪ The weathered (oxidised) portion of the MSM will be used as capping material on the final WRD landforms. The management strategies for the two main mineral waste streams remain: ▪ Stockpile the weathered component of the MSM for future use as WRD capping materials. Use weathered KYM overburden (classified as NAF) for future construction material for infrastructure including WRD and ROM pad bases. ▪ Stockpile, store and retain weathered and fresh rock mineral wastes (KYM and MSM and a small amount of waste rock comprising <30% Fe from the SIM) generated through cutbacks to access in the WRDs. These materials may have the potential to contain PAF and are to be stored in PAF Cell 1 within the F-East WRD in accordance with this AMD strategy. Undertake further ongoing operational geochemical assessment and sampling to validate the findings of the geochemical and risk assessments to date (refer Section 9). Construction of the WRD (Appendix A) included: ▪ AMD risks and waste rock management strategies and measures were identified, developed and implemented (Table 2.1 and PES, 2013a). ▪ Potential sources of AMD are inhibited and minimised by: o Installing a store and release cover to inhibit oxygen and moisture ingress. o Paddock dumping of waste rock in WRD with end dumping of PAF into lined cells with intermediate covers during the wet season to prevent/minimise exposure. o Encapsulation of PAF in 100,000m^3 volume containment cells constructed of NAF KYM within the WRD; cells have 2.5m thick bases and covers and 4.0m thick side covers. o Potential Backfilling and submergence of PAF wastes in open pits in future when available. o Ongoing identification and characterising of AMD generating wastes. ▪ The base of the WRD was constructed with 2m thick weathered impermeable NAF KYM. ▪ The cap of the WRD will be 1.2m thick NAF MSM covered by rock armour and 0.5m soil, placed and profiled for erosion control and slope stabilisation. ▪ Water management infrastructure: interception trenches, bunds/berms and sediment/ containment dams to control, capture and evaporate storm runoff.

	Self-heating of the PAF materials has not been observed. Self-heating and AMD potential are prevented or minimised through mine waste handling and storage as detailed above. The site is not dominated by PAF wastes: ▪ The volumes of PAF materials are small (Table 5, page 21, GHD 2015): Total % PAF in waste and ore is <1%. ▪ The PAF waste for the 2020-2023 Mining Plan is estimated at 2% compared to 72% NAF materials (refer Section 1.1).
6.2. Management of tailings to minimise AMD **6.2.1 Overview** **6.2.2 Water covers for tailings** **6.2.3 Covers for tailings**	The 2020-2023 Mine Plan (refer Section 4.4 above) entails removal of DSO material for processing by crushing which does not generate tailings.
6.3 Soil cover systems for waste rock **6.3.1 Covers on flat tops** **6.3.2 Treatment of outer slopes** **6.3.3 Cover design and performance**	Refer Appendix A and Section 6.1 above.
6.4 Blending and co-disposal of wastes	There is no blending or co-disposal of waste.
Section 7: Treatment of AMD (Handbook 2016)	
Management measures to prevent and contain AMD are appropriate and adequate. In the absence of AMD, treatment of AMD is not required; however, if AMD is detected, best practice treatment technologies and systems will be implemented.	
9c. A strategy for the ongoing monitoring of PAF material, including threshold trigger levels and mitigation responses.	
9.1 Introduction	Ongoing monitoring of PAF material under this plan is aligned and integrated with the: ▪ NRR Environmental Management System (MET00264379-029, November 2019). The EMS details the system for identifying, managing and monitoring environmental risks in accordance with AS 14001:2015. ▪ NRR Water Management and Monitoring Plan (MET00266522-011). The WMMP is a more specific/targeted supporting management and monitoring plan to support the 2020-2023 MMP. ▪ Stage 2 MMP - WRM water quality trigger values (MET00266251-004). This Memorandum (included in Appendix E) details a preliminary review of water quality data to derive trigger values suitable for the receiving waters for the Roper Bar Mine.

Overarching discussion of the performance evaluation process may be found in Section 9 of the EMS. Objectives and targets (note: trigger values are referred to as a type of target in these documents) appear in Section 6.3 of the EMS. Reference should also be made to Table 10-1 (surface water) and Table 10-3 (groundwater) in the WMMP.

Strategies and systematic approaches for ongoing monitoring of PAF materials are detailed in the earlier AMDMP's (references: PES 2013a, GHD 2015).

NRR is committed to provide adequate financial, human, technical and other resources in their operational budgets to ensure that continued monitoring will be in strict accordance with this document. Whilst there is a low risk of AMD post-mining, adequate provision will be made for mine closure. Current provisions include:

- A dedicated environmental officer will be responsible for undertaking the surface water monitoring program (to be undertaken as part of the environment officer's overall site responsibilities).
- External groundwater specialist has been budgeted for and will be engaged to monitor groundwater quality in accordance with the WMMP.
- Sampling and analysis work for the on-going geochemical testing program, including both *in situ* testing undertaken ahead of mining plus sampling and analysis of disturbed samples once placed in the dump to confirm the material characterisation. Budget allowance (based on sample numbers, approximately 300, in AMDMP): $40,000.
- Kinetic test columns to be installed with guidance from Pendragon Environmental Solutions and will be monitored and sampled by NRR environmental officer with samples submitted for analysis as per the monitoring program. Budget allowance for six columns: $20,000.

Sample characterisation during mining and grade control blast hole drilling, will be by Total %S by XRF measurement with a select number of representative samples submitted to a NATA credited laboratory for more detailed confirmatory analysis.

No sampling and analysis for AMD was undertaken since 2014 when the mine was placed in administration. However, visual observations of the covered PAF WRD have been made on monthly basis during the wet and early dry season with no indication of water ponding or precipitation of salts at the surface. Surface water samples are obtained monthly from the water retention and sediment dam RBSP01, which drains the Area F East WRD; the analytical data are collated in NRR Surface Water Monitoring Data database.

Monitoring of water quality in proximity of the mine (Appendix E) indicates that:

Surface Water and Impoundments:

- Surface flows are highly irregular and most samples are obtained from pools rather than flowing water.
- There is little difference in all analytes between the upstream (RBSW02) and downstream RBSW04) monitoring locations. pH is around 7.3 and EC 155μS/cm. Elevated concentrations of metals (Al, As, Fe and Mn), particularly Al above the trigger levels, occur up and downstream of the mine with no net increase in a downstream direction. Mean SO_4 concentrations are below 4mg/L.
- The water quality (potentially a mixture between rain water as the pits are currently flooded and groundwater influx) in the open pits (FE1, 2 and 3) have pH's between 6.5 and 7.1 and EC's between 1,542μS/cm and 2,499μS/cm. These waters have markedly higher elevated Mn and SO_4 concentrations than the surrounding surface waters.
- The water in the WRD sediment pond (RBSP01) has a pH of 7.8 and an EC of 6,702μS/cm. Metal concentrations are also elevated.

Groundwater:

- Groundwater quality is highly variable with a small difference between the upstream (RBGW01, MB18 and MB01) and downstream bores (RBGW02).

	▪ Mean pH range between 6.2 and 7.2 and mean EC's between 7,405µS/cm and 14,578µS/cm. These waters have markedly higher elevated metal and SO_4 concentrations than the surrounding surface waters. Trends in the water monitoring data (Appendix E) indicate that: ▪ It is evident that natural causes i.e. rainfall and evaporation impacts water quality. ▪ Mean pH of surface (including open pits and WRD) and ground waters fall in a band between 6 and 8 and predominantly around the 7 level. The higher pH's are associated with impounded mine waters. ▪ Larger EC's, SO_4 and metal concentrations are associated with the open pits and WRD but there is no distinct indication (between upstream and downstream monitoring locations) and/or trend that mining has impacted the downstream receiving environment.

9.2 Performance Evaluation	Refer Appendix 1 Table A1 – Elements of an AMD Monitoring Program below.
	The following performance criteria will be met to confirm effective handling and management of waste materials:
	▪ No discharge of water that was in contact with PAF waste materials unless permitted and in compliance with a Waste Discharge Licence (WDL). Contaminated water will be contained and evaporated.
	▪ Maintain ambient downstream surface and groundwater qualities particularly pH.
	▪ Maintain soil pH in the range 6.0 to 8.5 or at ambient pH values.
	▪ Account for all sources of acidity: Total Sulfur >0.30% S.
	▪ Monitor grade control bores at 10m lines and 1m sample intervals for total S with PAF >0.30% Total S.
	▪ Monitor blast holes at 10m intervals to accurately delineate extent of PAF.
	▪ Selective materials with Total S values of between 0.25% and 0.30% will undergo further testing by measurement of paste pH and/or NAG pH. Paste pH values of <4.6% and NAG pH levels of <4.5% will trigger the requirement for laboratory analytical assessment of ABA. Total S values of >0.3% will trigger the requirement for further field paste pH and NAG measurement and ABA laboratory assessment.
	The accuracy of field laboratory XRF testing is to be calibrated by analysing at least 10% of the samples in a NATA accredited analytical laboratory. Additional laboratory analyses will be required if there is poor correlation between field testing and laboratory analysis including field classification and those that would be assigned upon the results of the laboratory testing.
	NRR has a response process applicable to identified objectives and targets in the event a trigger value is exceeded (EMS, NRR 2019a; WMMP, NRR 2019b and Appendix E of this plan). The trigger value exceedance response process is detailed in Section 9.1.3 (includes explanatory text as well as a flowchart of the response process) of the EMS and also in Section 11 of the WMMP.
	Monitoring parameters were identified based upon risk, analytical data obtained thus far and Appendix 1. Default trigger values (Performance Evaluation Criteria) are to be employed (based on ANZECC/ARMCANZ [99% Ecosystem Protection], ADWG [Livestock] and relevant AMD guidelines) until site specific triggers are developed and approved as part of this plan.
	Upon exceedance of a trigger value the following will be undertaken:
	▪ Initial validation of data via a review of the monitoring result(s) against the Performance Evaluation Criteria. This will include collection and analysis of confirmatory samples and comparison of results against any upstream (reference) and downstream (receiving environment) monitoring locations.
	    o If the upstream (reference) value is the same as the downstream (receiving environment) value or exceeds the trigger value, then no further action will be taken; or
	    o If the upstream (reference) value is less than the downstream (receiving environment) value and the downstream value exceeds the trigger value an investigation will commence.

- If the internal review confirms that a target (trigger value) was exceeded, and is potentially mine derived, NRR will provide written notification to the administering authority within 24 hours and include a justification of why an investigation commenced.
- Where an exceedance of a trigger level has occurred and is being investigated then no further reporting will be undertaken for subsequent trigger events for that monitoring parameter.

Incident investigation:

- Incident investigations will be undertaken in accordance with both Section 29 of the NT Mining Management Act as well as in accordance with the ANZECC/ARMCANZ 2000 Guidelines with the goal to identify and mitigate potential sources of environmental harm (this may include additional follow up monitoring to confirm initial monitoring results).
- Within 10 business days after notifying the administering authority of a potential mine derived trigger exceedance, or receipt of follow-up monitoring results (whichever is the latter), the outcome of the investigation will be provided to the administering authority, including the results and interpretation of any samples collected and analysed, outcomes of actions taken at the time to prevent or minimise environmental harm and corrective actions to mitigate potential impacts from the exceedance and to prevent a recurrence of the incident.

Management responses

Based on the recommendations of the incident investigation, NRR will:

- Prepare a report on corrective actions for subsequent review by the administering authority.
- Update/modify relevant environmental management plans (EMPs) via the existing MMP process (this may include updates to analytical parameters, targets/trigger levels, operational procedures and/or management and monitoring plans).
- Implement corrective actions.

In addition, EMPs may be updated following on regular performance reviews by management.

9.3 Conceptual Site Model (CSM) of AMD Processes

The conceptual site model (CSM) considers the source, pathway receptor concept (INAP, 2009). The source material risk was obtained from earlier geochemical assessments (PES, 2013a and GHD, 2015) with the receptors (summary by GHD, 2015) drawn from the Roper Bar EIS (EcOz, 2012).

Sources	*In situ* Sulfides		*Ex situ* Sulfides	
	Within pit floors and walls above the water table (F East, E East, refer Block Models Appendix D)		Mined and placed in WRD PAF Cells as waste. Total identified waste in WST (Table 1.1) Materials stockpiled on the ROM Pad	
	Metals: no elevated whole rock assay metals using the GAI (PES, 2013, GHD, 2015)			
	Metals leaching: some minor metals from KYM unit possible (PES 2013, GHD, 2015)			
	Sulfate leaching: possible (PES 2013, GHD, 2015)			
Pathways	Surface Water	Groundwater	Sediment	Windborne Dust
Receptors	Aquatic flora and fauna in surface waters downstream in the Towns River including freshwater sawfish (Pristis microdon)			
	Informal camping site on the Towns River, Nathan River Rd, some 15km north east of mine			
	A sacred billabong north of F East Open Pit (Site Reference AAPAC2013/034/RWA1			
	Various springs and Groundwater Dependent Ecosystems (GDE's)			
	The Towns River and associated alluvium			

AMD risk assessments in accordance with Section 2.1 and Table 2.1 above (PES, 2013a and GHD, 2015) concluded that:

	▪ The risk is considered low and manageable. The volume of PAF materials is small when compared with the volume of NAF materials available for containment. ▪ With appropriate design and effective control measures, the residual AMD risk will remain low through the care and maintenance phase. AMD risks will be monitored in accordance with this document.
9.4 Monitoring	Refer Appendix 1 Table A1 – Elements of the AMD Monitoring Program below. Monitoring of: ▪ the constructed landforms: Open Pits, WRD's, ROM Pads, LGO stockpiles, surface water control measures, ▪ surface and ground water; and ▪ pit wall seepage, provide critical feedback to confirm that the operational measures and controls are effective for their stated aim. An outcomes based approach is utilised as informed by adaptive management to meet site specific trigger values that are to be developed over time as data is gathered. **Geochemical Monitoring** Additional geochemical monitoring was identified during a gap analysis (GHD, 2015) to refine the AMD risk from all key lithologies and increasing the confidence in the AMD strategy and management. Laboratory XRF analysis on samples obtained during grade control and subsequent blast holes, coupled with targeted drilling to refine the lateral and vertical extent of PAF materials particularly where there is a paucity in data, remains the primary measures for determining Total S. This methodology provides for an auditable process with quality data despite longer turn-around times. **Static Testing** A better understanding of the pyritic sulfur content is required, particularly for the weathered KYM, MSM and SIM units where much of the Total Sulfur may be non-reactive. This will be achieved by having the samples (in addition to Total Sulfur) analysed for detailed Acid Base Accounting. Recommended sample numbers are (GHD, 2015): ▪ 75 samples from the KYM, ▪ 140 samples from the MSM; and ▪ 27 samples from the SIM units, which in terms of sample frequencies equate to 1 sample from each of the lithologies per 200,000t DSO mined. **Kinetic Testing** The six kinetic columns established earlier have been destroyed by fire and monitoring was discontinued when the mine was placed in care and maintenance in 2015. New kinetic leach columns, using the AMIRA 2002 method, representative of the fresh and weathered portions of the three main geological units (KYM, MSM and SIM) will be established when mining recommences. The effectiveness or availability of any neutralising minerals present in the key lithologies will be ascertained using acid buffering characteristics curves (ABCC) for each of the leach columns. Additional ASLP testing will be undertaken to gain a better understanding of the metal leaching potential of each geological unit (KYM, SIM and MSM). Some additional data will be obtained during leaching of the columns; the ASLP results will be validated against the column metals leaching results.

	Surface and Groundwater Monitoring The locations, sampling procedures, schedule and analytes for surface and ground water monitoring with reference to AMD are entirely consistent with the WMP and are therefore not replicated here. Analytes with specific reference to AMD monitoring include pH, EC, acidity and alkalinity, sulfate and metals particularly aluminium, arsenic, iron and manganese.
9.4.1 Monitoring Parameters	Refer Appendix 1 Table A1 – Elements of the AMD Monitoring Program below.
9.5 Data storage, evaluation and reporting	Assay results are received from the laboratory, verified for QA/QC, then imported into the database. Spatial results are imported into Surpac for the delineation of PAF outlines in the flitch dig plans (refer Appendix F).

Appendix 1: Table A1 – Elements of the AMD Monitoring Program.

The facilities at Roper Bar are tabulated below:

Facility	Component	Parameters Measured	Frequency	Monitoring Methodologies and Trigger Values (Performance Evaluation Criteria)*1
General	Rock Type	Lithology, weathering state, sulfide and carbonate content	Log all drill core	Sections 4.4, 9.1, 9.2 and 9.4
	Surface water: up- and downstream	Flow rate	Event based	Sections 9.1, 9.2 and 9.4 and Appendix E ANZECC-ARMCANZ 2000 (99% Ecosystem Protection)
		Field Water Quality Parameters: pH, EC/TDS, DO and ORP	Daily/weekly/monthly event based	
		Laboratory: TSS, acidity, alkalinity, major chemistry, metals	Daily/monthly/event based	
	Groundwater: up- and down-gradient	Groundwater levels, flow rate, direction	Quarterly	Sections 9.1, 9.2 and 9.4 and Appendix E ADWG 2018 (Livestock)
		Field Water Quality Parameters: pH, EC/TDS, DO and ORP	Bi-annual	
		Laboratory: TDS, acidity, alkalinity, major chemistry, metals/metaloids	Bi-annual	
	Site Water Balance	Flow rate, pump rate, acidity load	Daily	Sufficient but not excessive volume of water
		Water levels and volumes in storage facilities	Daily	
	Discharge Points	Flow rates	Daily/event based	Water quality parameters for Waste Discharge Licence Sections 9.1, 9.2 and 9.4 and Appendix E ANZECC-ARMCANZ 2000 (99% Ecosystem Protection)
		Field Water Quality Parameters: pH, EC/TDS, DO and ORP	Daily/event based	
		Laboratory: TDS, acidity, alkalinity, major chemistry, metals/metaloids	Monthly/quarterly/event	
	Production Geochemistry	Geochemical classification of soil/rock (static tests)	Waste characterisation drilling, grade control drilling and blast holes	Sections 9.2 and 9.4 >0.3% Total S PAF
WRD's, Ore Stockpiles	Waste rock and ore materials	Production rates, mass/volume of waste rock and ore piles	Daily	Sections 4.4 Mine Schedule, 9.2 and 9.4
		Geochemical characterisation of lithologies (static and kinetic tests)	As required	Sections 9.2 and 9.4 >0.3% Total S PAF

	Surface water runoff and seepage	Flow rates	Monthly	Sections 9.2 and 9.4
	Surface water quality	Field Water Quality Parameters: pH, EC/TDS, DO and ORP	Monthly/event	Sections 9.2 and 9.4 Water quality criteria for site use and Waste Discharge Licence (WDL). ANZECC-ARMCANZ 2000 (99% Ecosystem Protection) ADWG 2018 (Livestock)
		Laboratory: TDS, acidity, alkalinity, major chemistry, metals/metaloids	Monthly	
	Groundwater	Water levels in stockpiles/WRD	Monthly/event	Sections 9.2 and 9.4
	Groundwater: up- and down-gradient and at the WRD/stocpiles	Field Water Quality Parameters: pH, EC/TDS, DO and ORP	Bi-annual	Sections 9.2 and 9.4 Water quality criteria for site use and Waste Discharge Licence (WDL). ANZECC-ARMCANZ 2000 (99% Ecosystem Protection) ADWG 2018 (livestock)
		Laboratory: TDS, acidity, alkalinity, major chemistry, metals/metaloids	Bi-annual	
Open Pits	Pit-wall material (cone of depression)	Lithology, weathering state, sulfide and carbonate content	As mining progresses (representative samples from each lithology and weathering state)	Sections 4.4, 9.1, 9.2 and 9.4
	Pit stormwater and influx	Dewatering pump flow rates	Daily	Sections 9.2 and 9.4
	Pit water quality	Field Water Quality Parameters: pH, EC/TDS, DO and ORP	Monthly	Sections 9.2 and 9.4 Water quality criteria for site use and Waste Discharge Licence (WDL). ANZECC-ARMCANZ 2000 (99% Ecosystem Protection) ADWG 2018 (Livestock)
		Laboratory: TDS, acidity, alkalinity, major chemistry, metals/metaloids	Monthly	
	Pit groundwater (cone of depression)	Groundwater levels, flow rates for dewatering bores	Quarterly	Sections 9.2 and 9.4
		Field Water Quality Parameters: pH, EC/TDS, DO and ORP	Bi-annual	Sections 9.2 and 9.4 Water quality criteria for site use and Waste Discharge Licence (WDL). ANZECC-ARMCANZ 2000 (99% Ecosystem Protection) ADWG 2018 (Livestock)
		Laboratory: TDS, acidity, alkalinity, major chemistry, metals/metaloids	Bi-annual	

99% Aquatic Ecosystem Protection (ANZECC-ARMCANZ):

pH	EC	DO	Ag_F	Al_F	As_F	B_F	Cd_F	
6 to 8	20 to 250	80 to 110	0.02	27	0.8	90	0.06	
Cu_F	**Fe_F**	**Mn_F**	**Mo_F**	**Ni_F**	**Pb_F**	**Se_F**	**U_F**	**Zn_F**
1	300	1.2	34	8	1	5	0.5	2.4
EC in µS/cm; DO in % and metal concentrations in µg/L.								

Stock Drinking Water Limits (ADWG):

pH	EC	Al_F	As_F	B_F	Cd_F	Cr_F	Cu_F	Mn_F	Mo_F
4 to 9	5,970	5,000	500	5,000	10	1,000	1,000	10,000	150
Ni_F	**Pb_F**	**Se_F**	**U_F**	**Zn_F**	**Al_T**	**As_T**	**Cd_T**	**Cr_T**	**Cu_T**
1,000	100	34	200	20,000	5,000	500	10	1,000	1,000

Mn_T	Ni_T	Pb_T	Se_T	Zn_T	Ca_F	Mg_F	Sulphate
10,000	1,000	100	34	20,000	1,000	1,000	1,000

EC in µS/cm; metal concentrations in mg/L.

Elements of Monitoring Program: to be reviewed continuously and expanded pending trends in monitoring data.

AMDMP Review	This AMDMP will be implemented prior to commencing with the 2020-2023 Mine Plan and will be updated frequently where required and for future operations. There is a statutory requirement for the AMDMP to be reviewed: ▪ In accordance with Condition 16 of the Commonwealth Environmental and Biodiversity Conservation Act 1999 (EPBC) approval for the ongoing protection of the freshwater sawfish (*Pristis microdon*), the AMDMP must be reviewed annually from the date of first approval of the AMDMP (until two years following the closure of Area F-East Pit 3 (now referred to as Area F West Pit 1) by the independent technical reviewer, to enable continuous improvement and adaptive management of PAF material management. ▪ From two years following the closure of Area F-East Pit 3 (now referred to as Area F West Pit 1), the AMDMP must be reviewed by the independent technical reviewer once every three years for the remaining life of the project. Furthermore, any activity not previously authorised under the approved AMDMP must be incorporated into a revised AMDMP for review and approval by the Commonwealth Minister for the Environment in accordance with Condition 5. Revised plans would not be approved by the Minister unless they provided equivalent or improved environmental outcomes over time. Item 3 of the Schedule under the NT DME (now DPIR) approval, it is required that the MMP must at intervals not exceeding 12 months from the anniversary of the date of the authorisation (or such other date as nominated by WDR and as approved by the Minister), be reviewed. Since the AMDMP forms an attachment to the MMP annual reviews are required notwithstanding the Commonwealth conditions of approval. In general, the annual review of the AMDMP will be guided by the assessment of risks (Table 2.1 and associated procedure) and will be developed in a staged approach to: ▪ Evaluate and incorporate new potential hazards and their associated impacts. ▪ Accommodate design modifications due to variability between predicted and actual constructed landforms. ▪ Avoid negative consequences from design-non-conformances. The revised AMDMP will be used to inform future revisions of the Mine Closure and Rehabilitation Plan for the site.
Contingency Plan	Contingency plans are required where residual risk remains after the application of AMD prevention and control measures. Contingency planning therefore include targeted monitoring, trigger levels for actions and specific responses in case a certain event occurs i.e. a failure mode is the potential for AMD seepage from a waste rock pile, then monitoring can be established for sulfate concentrations in waste rock seepage as an early indicator of potential AMD formation. Following the above if significant increases in sulfate concentrations are measured, then the most appropriate contingency measure such as temporary or permanent covers and/or drainage collection and treatment will be implemented. Where monitoring parameters exceed trigger values, a *root cause* analysis will be undertaken whereby the causal link for the water quality exceedance will be determined to then implement a corrective action, including an alternate management strategy if necessary, to eliminate future risk of a repeat. Future revisions of this document would also inform forward AMD risk management by providing a more robust data set to inform AMD risk, and therefore, any adjusted management strategy.

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Appendices

Appendix A: Constructed WRD and PAF Cell.

Appendix B: Independent Technical Review: Amanzi Consulting, 2019.

Appendix C: Standard Operation Procedure: Field Tests.

Appendix D: F East and F West Block Models.

Appendix E: Water Quality Monitoring and Trigger Values.

Appendix F: Standard Operating Procedure: Data Storage and Processing.

Appendix A: Constructed WRD and PAF Cell.

Legend

- fe_wrd_paf_cell_stage_2-mardi
- fe_wrd_paf_cell_stage_2

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- CADASTRE SOURCED LANDGATE 2016
- LOCALITY MAP SOURCED LANDGATE 2006
- AERIAL PHOTOGRAPHY SOURCED NEARMAPS 28.01.16

pendragon environmental solutions

0 100 200 300 400 metres

N

Scale: 1:13,582,053 @ A3
GCS GDA 1994

LOCALITY MAP

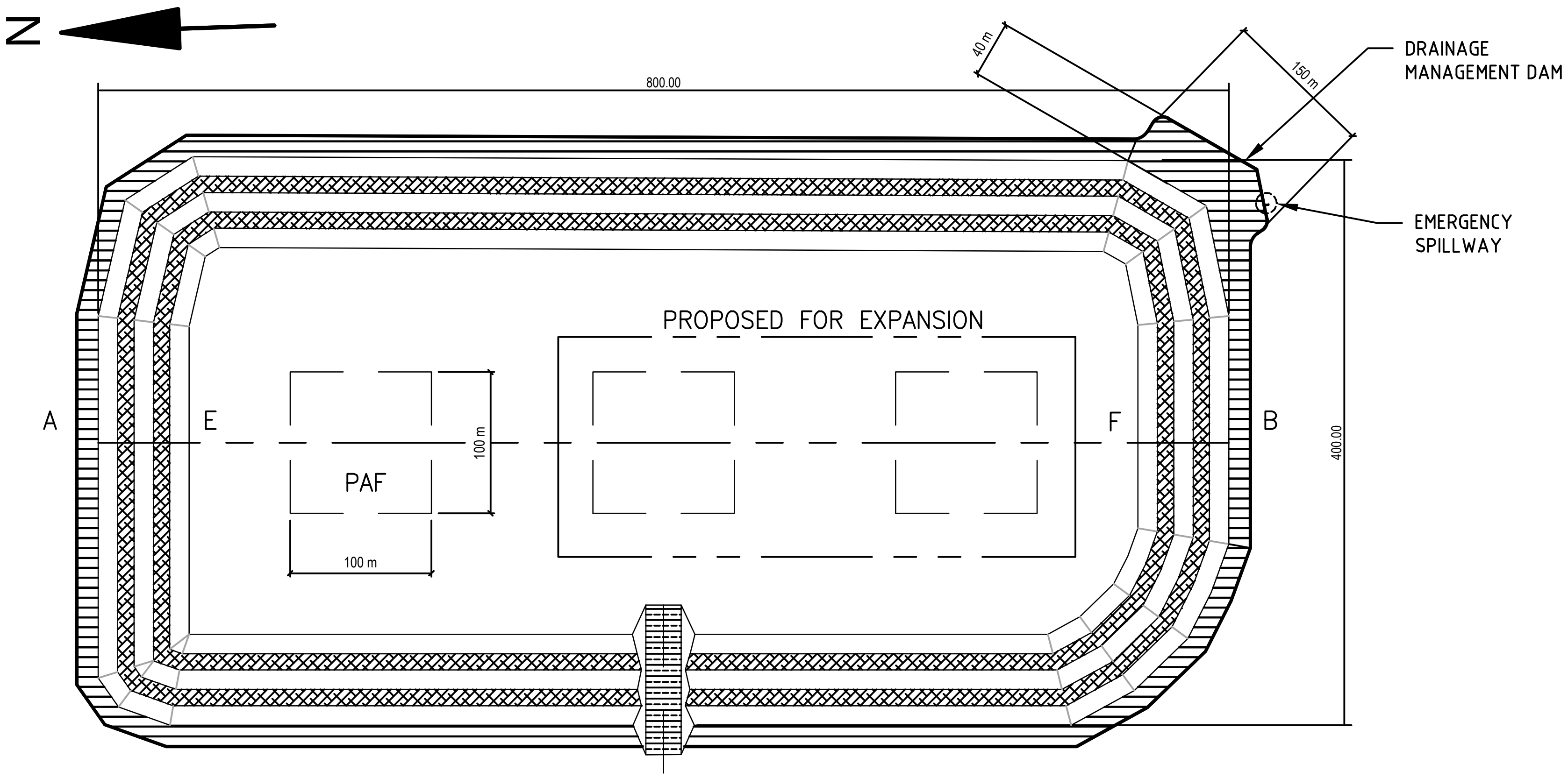
CREATED BY	JOB NUMBER	DATE	REVISION
ENVIRONMAPS	PES19017	27/11/2019	0

Client:

FIGURE NUMBER
FIGURE TITLE

ENVIRONMAPS Environmental Mapping Solutions t: 0406 590 006 www.environmaps.com.au

C:\GIS\Jobs\Pendragon\PES19017 - Nathan River Resources\Figures\PES19017_BASE_191127.mxd



PLAN
SCALE 1:5000

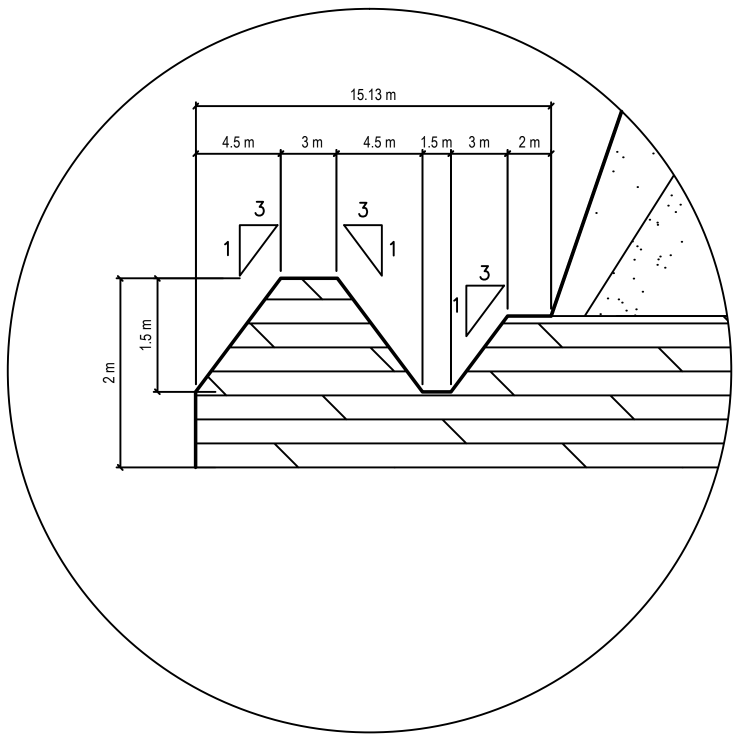
LEGEND

COVER SYSTEMS

- Top Spoil/Moroak Sandstone (1.5 m)
- Compacted Clay Seal (0.5 m)
- Trafficked-compacted NAF Materials (1.0 m)
- Fine and Coarse Grained Loose-end dumped Wasted rock.

PAF CELLS

- Crushed and compacted NAF Kyalla Formation Siltstone (4 m and 2.5 m as shown)
- PAF
- Foundation (NAF Kyalla Formation Siltstone (+/- 2 m thick)



DRAINAGE SYSTEM DETAIL 1
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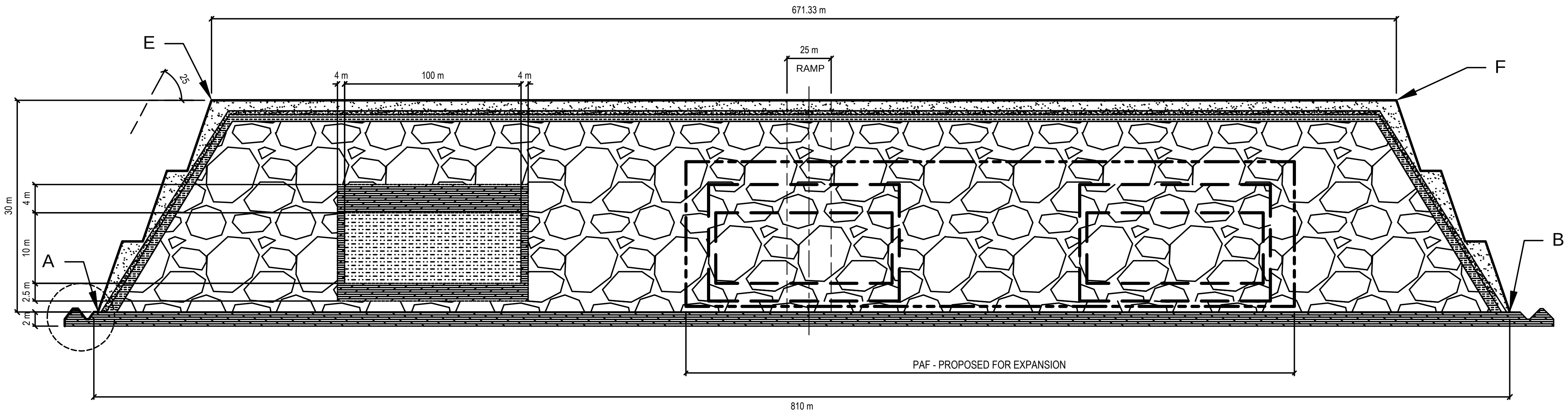

SECTION NW-SE
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CLIENT DWG No. DWG–.....–.....–.....									
E-EAST WRD									
–	–	A	DATE	ISSUED FOR REVIEW	AMBY	EAL	EAL	–	–
DWG No	REFERENCE DRAWINGS	REV	DATE	REVISION DESCRIPTION	DRAWN	CHECKED	DESIGNED	APPROVED	CLIENT

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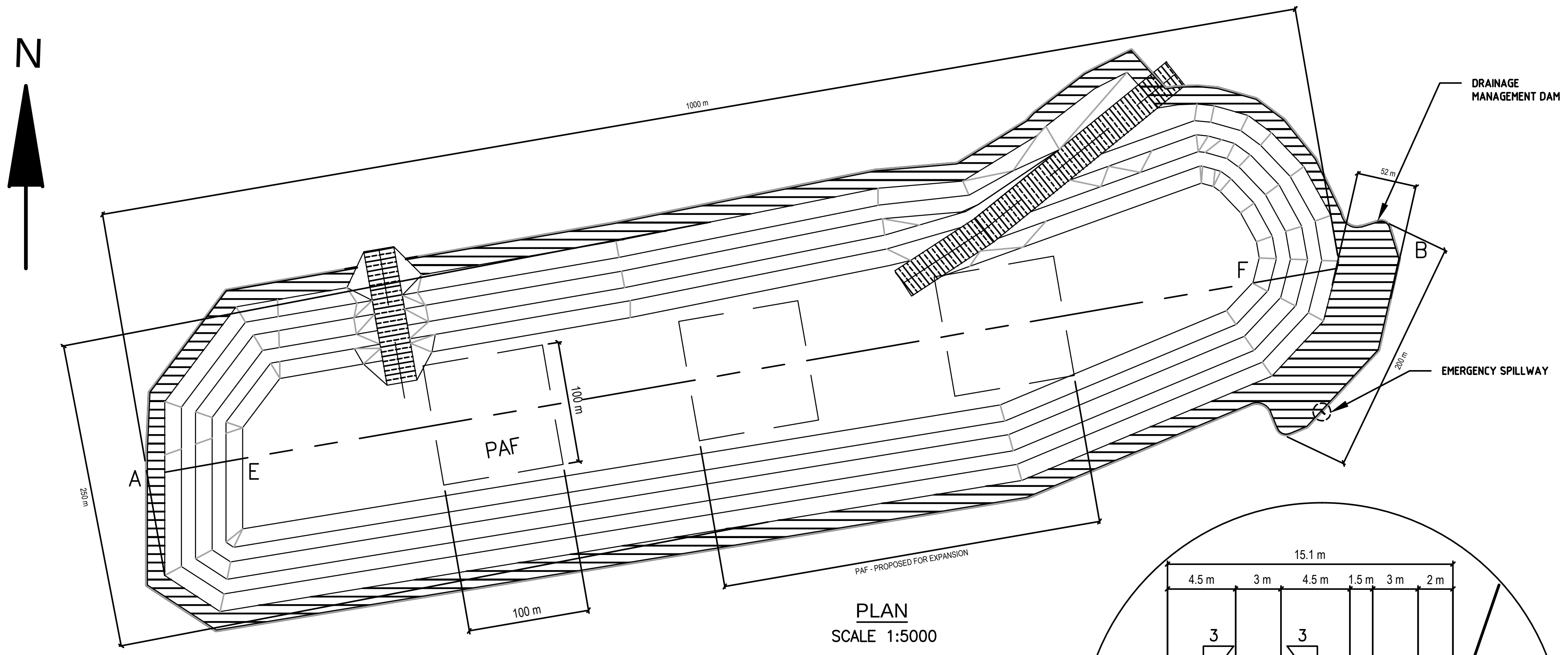
DRAWN:	AMBY	DATE:	APR 13
CHECKED:	EAL	DATE:	
DESIGNED	EAL	DATE:	
APPROVED:		DATE:	
CLIENT:	WDR	DATE:	

TITLE:
WESTERN DESERT RESOURCES
PAF PLAN AND SECTION

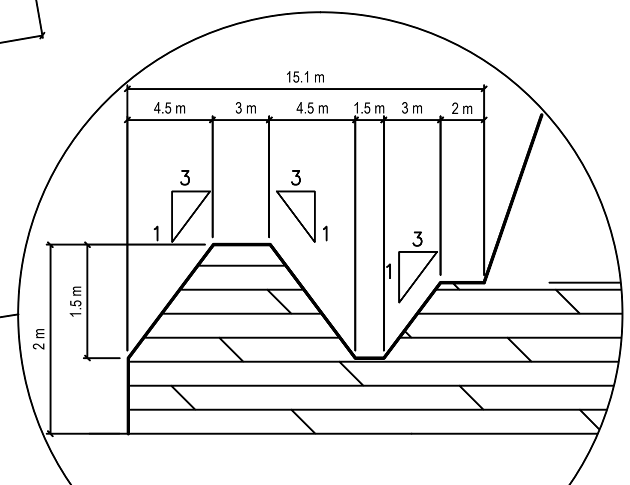
SCALE: AS SHOWN | DRG No. | REV A



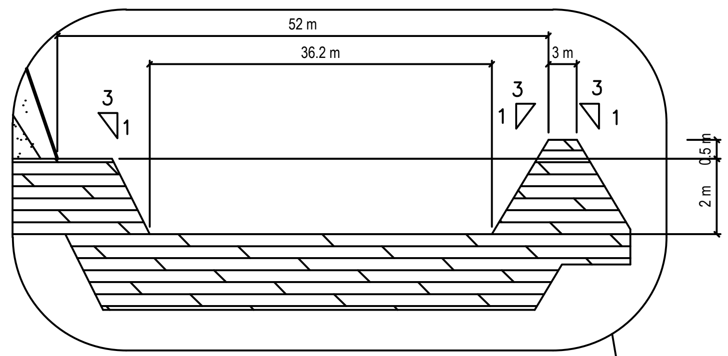
PLAN
SCALE 1:5000

LEGEND

COVER SYSTEMS		Top Spoil/Moroak Sandstone (1.5 m)
		Compacted Clay Seal (0.5 m)
		Trafficked-compacted NAF Materials (1.0 m)
		Fine and Coarse Grained Loose-end dumped Wasted rock.
PAF CELLS		Crushed and compacted NAF Kyalla Formation Siltstone (4 m and 2.5 m as shown)
		PAF
		Foundation (NAF Kyalla Formation Siltstone (+/- 2 m thick)



DRAINAGE SYSTEM DETAIL 1
SCALE H=1:400 V=1:100



DRAINAGE MANAGEMENT DAM
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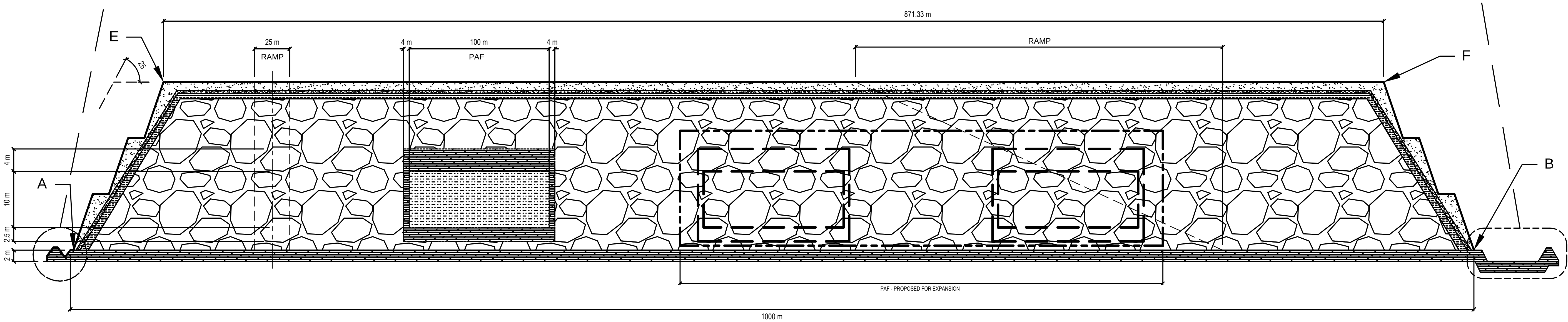


SECTION SW-NE
SCALE H=1:3000 V=1:750

CLIENT DWG No. DWG–.....–.....–.....

F-EAST
WRD

–	–	A	DATE	ISSUED FOR REVIEW	AMBY	EAL	EAL	–	–
DWG No	REFERENCE DRAWINGS	REV	DATE	REVISION DESCRIPTION	DRAWN	CHECKED	DESIGNED	APPROVED	CLIENT

pendragon environmental solutions
Leaders in Environmental Practice
PENDRAGON ENVIRONMENTAL SOLUTIONS Pty. Ltd.
Suit 1, 131 - 135 Rokeby Road, Subiaco, WA 6008
Tel: +61 8 9382 8286 - Fax: +61 8 9382 8393

DRAWN:	AMBY	DATE:	APR 13
CHECKED:	EAL	DATE:	
DESIGNED	EAL	DATE:	
APPROVED:		DATE:	
CLIENT:	WDR	DATE:	

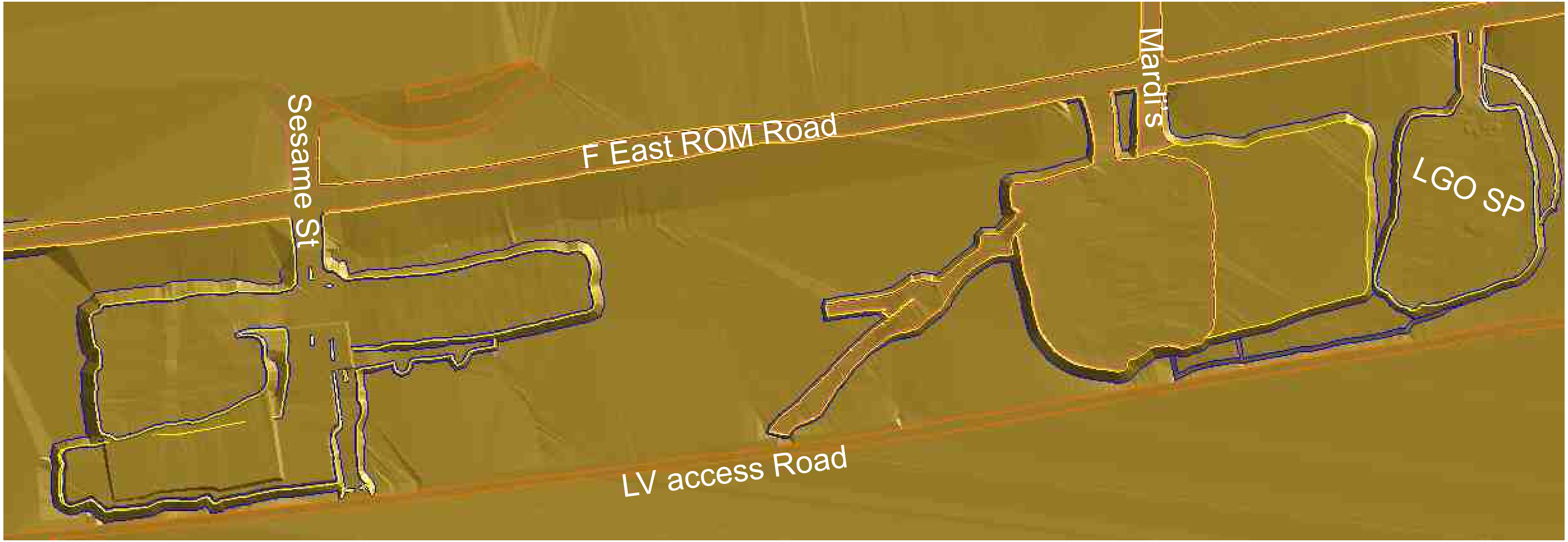
TITLE:
WESTERN DESERT RESOURCES
PAF PLAN AND SECTION

SCALE: AS SHOWN
DRG No.
REV A

F East PAF Cell construction

08/06/2014

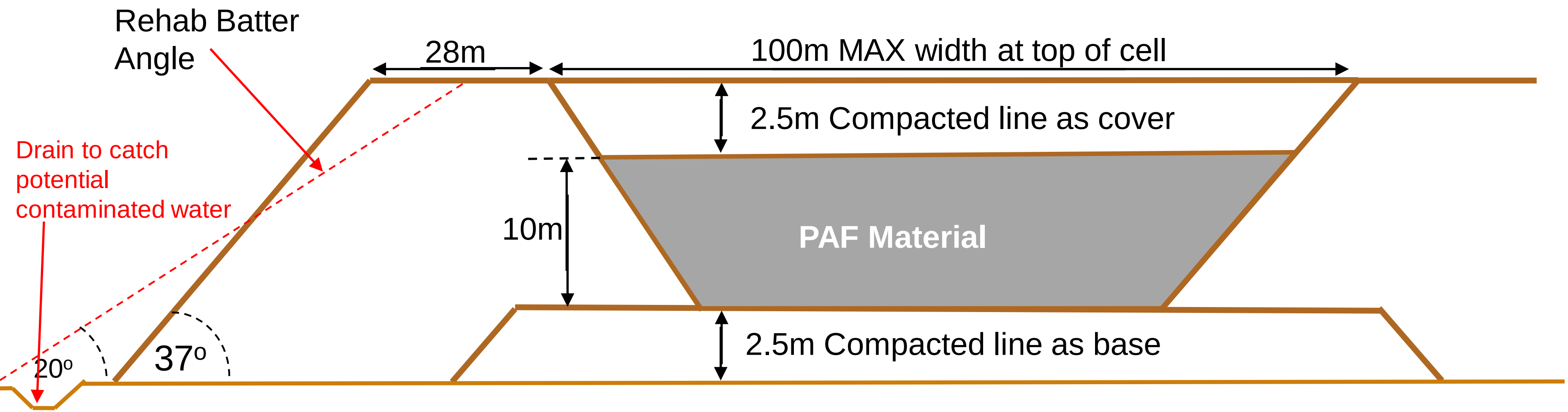
F East PAF Cell Overview



1. Construct cells in FE WRD for Containment of Potential Acid Forming Material
2. Construction of Cells in compliance with WDR AMD Management Plan.
3. PAF cells storage capacity to contain predicted 1.5 Mbcm predicted PAF material to reside within the F East Pit.
4. PAF cell designed to ensure capacity is continually increased.
   - Contingencies to emergency containment of PAF material during a rain event are outline on page 7.

Construction Guidelines

See below the minimum requirements for construction of a PAF cell (AMDMP,2014)



1. PAF cell must be constructed at the centre of the dump.
2. Nominal design of 100m x 100m x 10m
3. Compacted base, sides and cover constructed out of NAF (non-acid forming) Kyalla material.
4. Minimum base and cover thickness of 2.5m (post compaction).
5. Minimum side width of 28m to ensure PAF is a minimum of 13m away from rehab batter

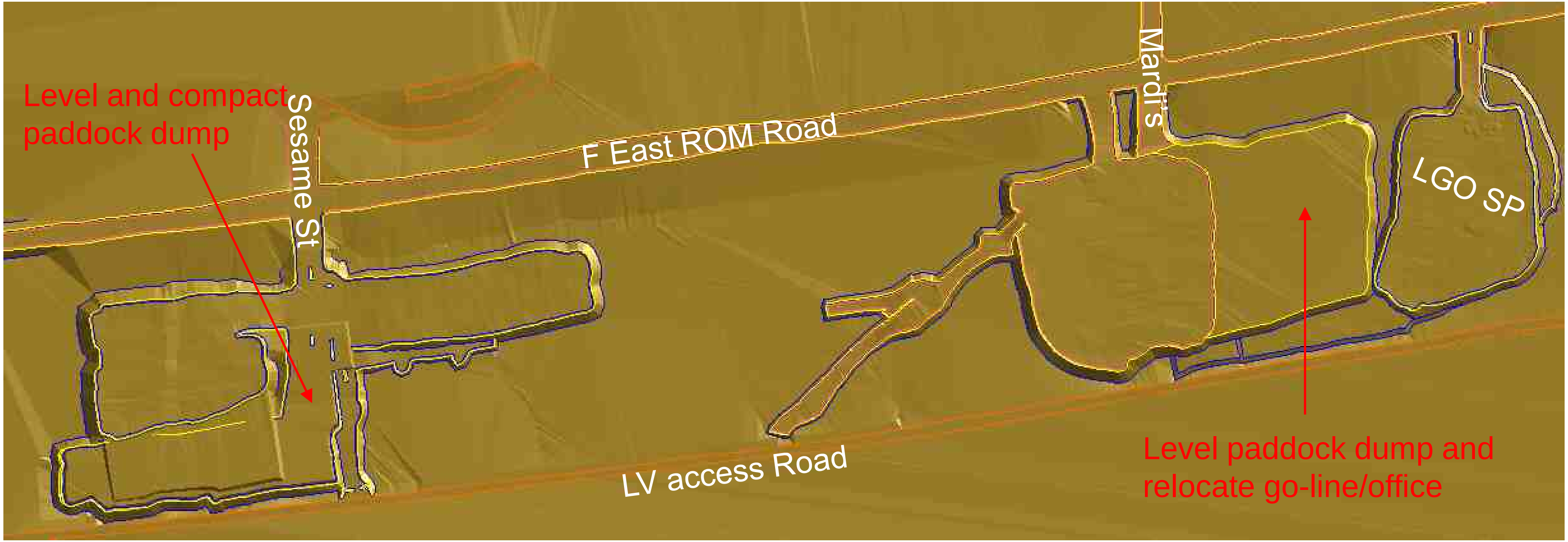
FE PAF Reserves

F-East PAF reserves as per current 3 month schedule.

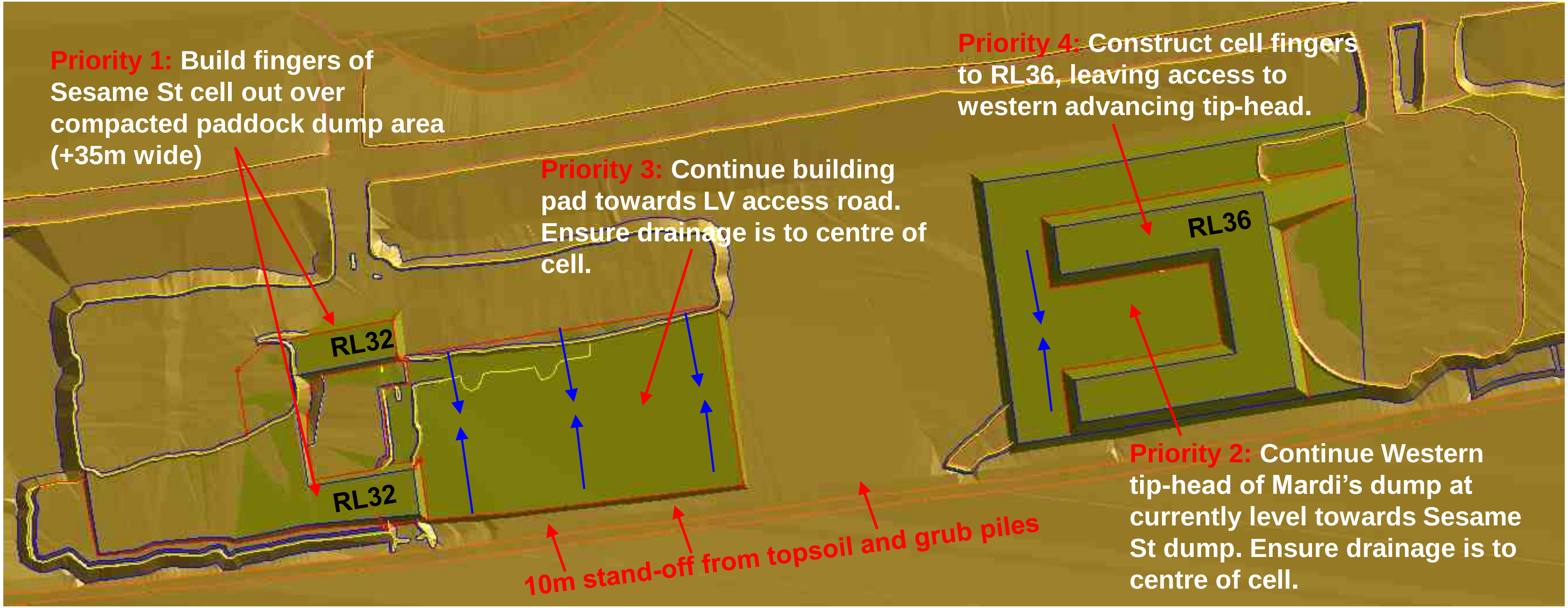
	FE23		FE1	
	PAF reserves	**NAF Reserve**	**PAF reserves**	**NAF Reserve**
June	15,992	703,510	6,580	125,094
July	41,549	548,065	185	286,594
August	30,037	208,568	26,851	482,454
Total	87,578	1,460,143	33,616	894,142

Total reserves are as per current approved pit shell is approximately 1.5 Mbcm.

FE WRD PAF Cell Stage 1
Prep Work



FE WRD PAF Cell Stage 1



Construction volume:

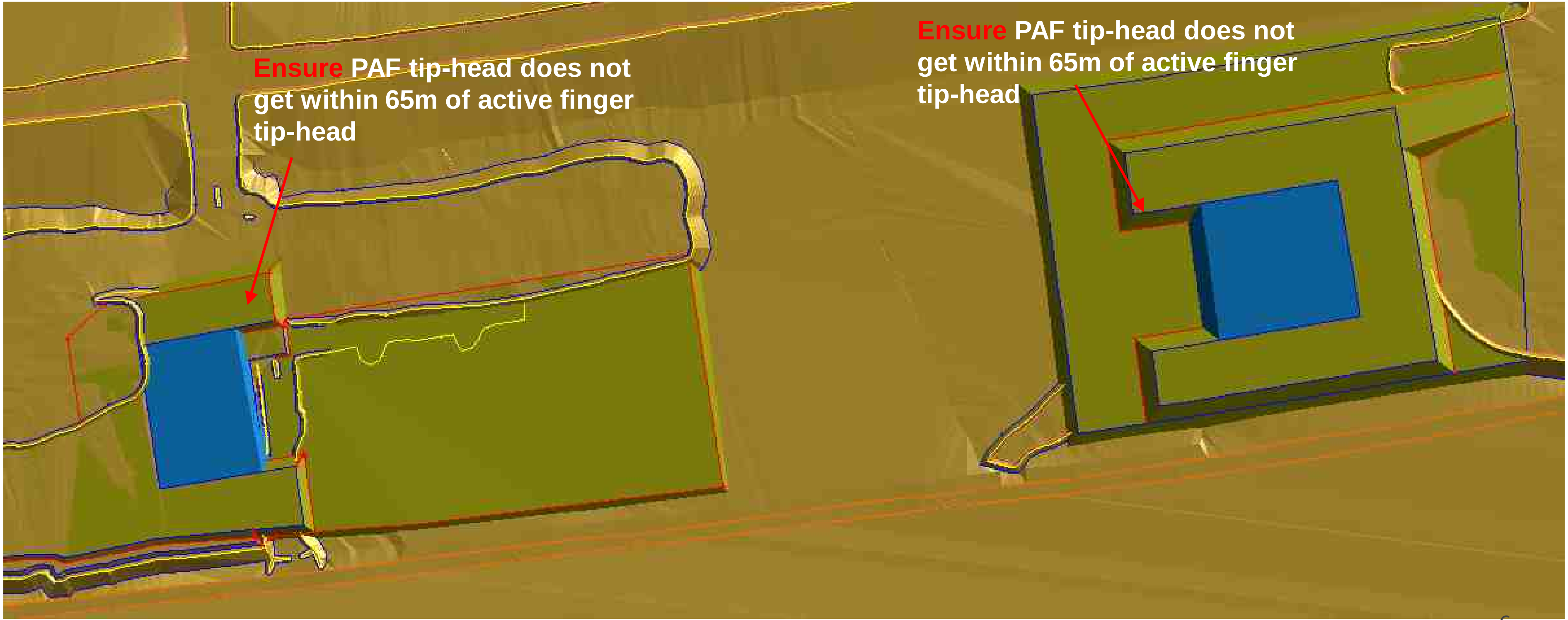
- Sesame St: 176,900 bcm
- Mardi's: 565,150 bcm

Cell Holding Capacity:

- Sesame St: 19,450 bcm
- Mardi's: 48,700 bcm

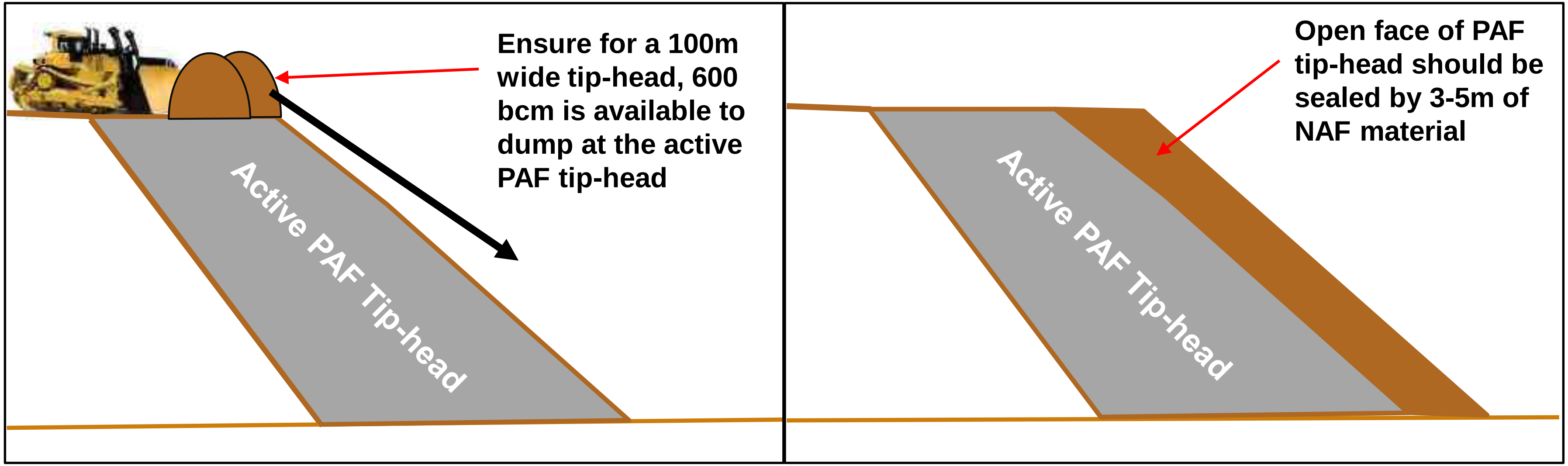
FE WRD PAF Cell Stage 1

PAF Dumping

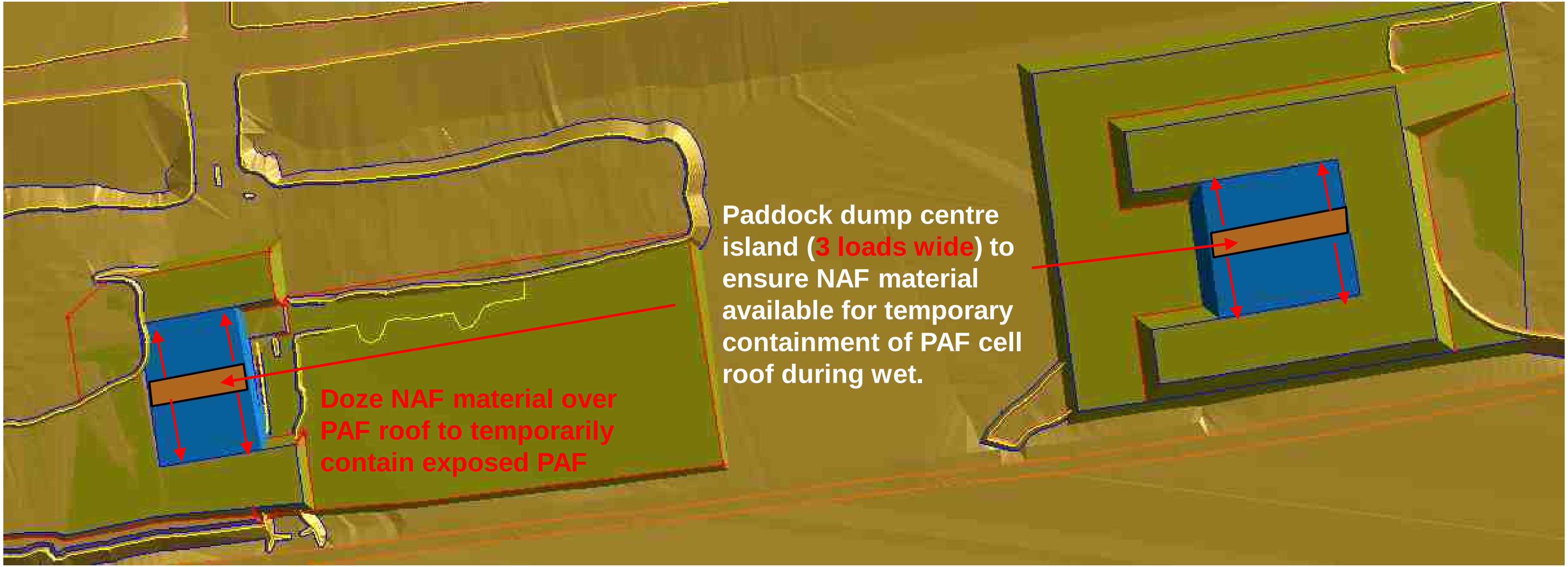


FE WRD PAF Cell Stage 1

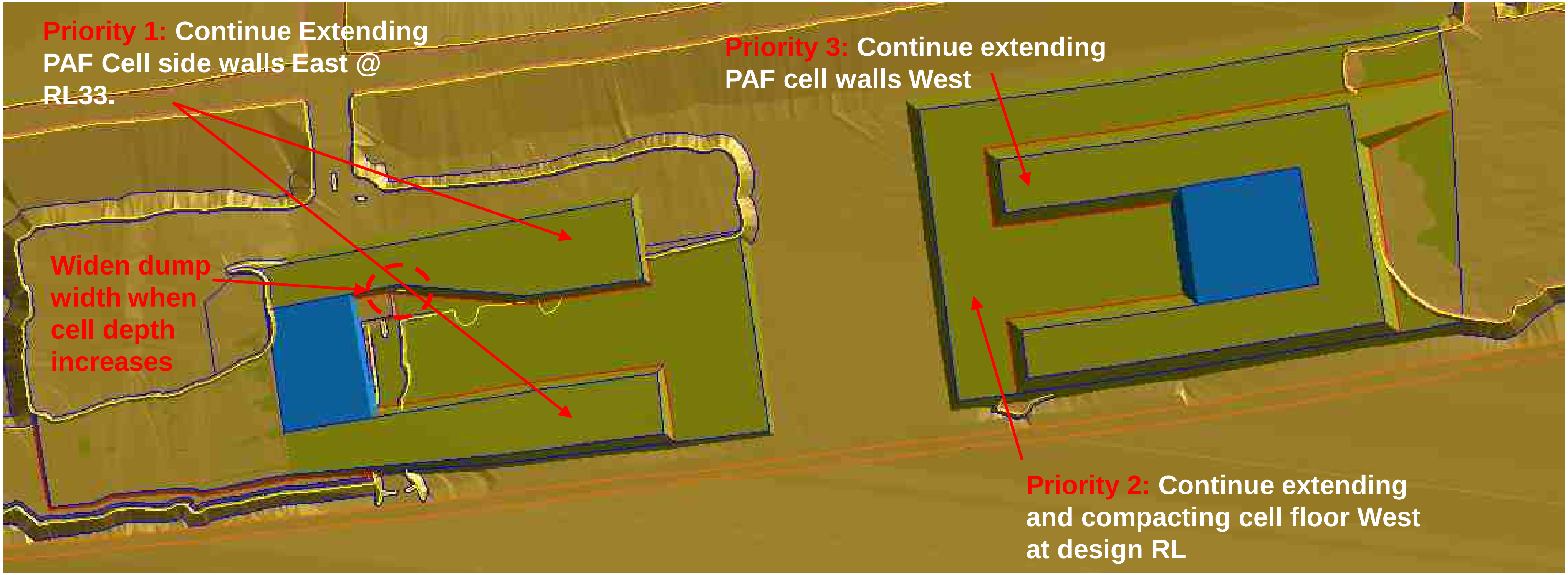
PAF Emergency Containment Plan



FE WRD PAF Cell Stage 1
PAF Emergency Containment Plan



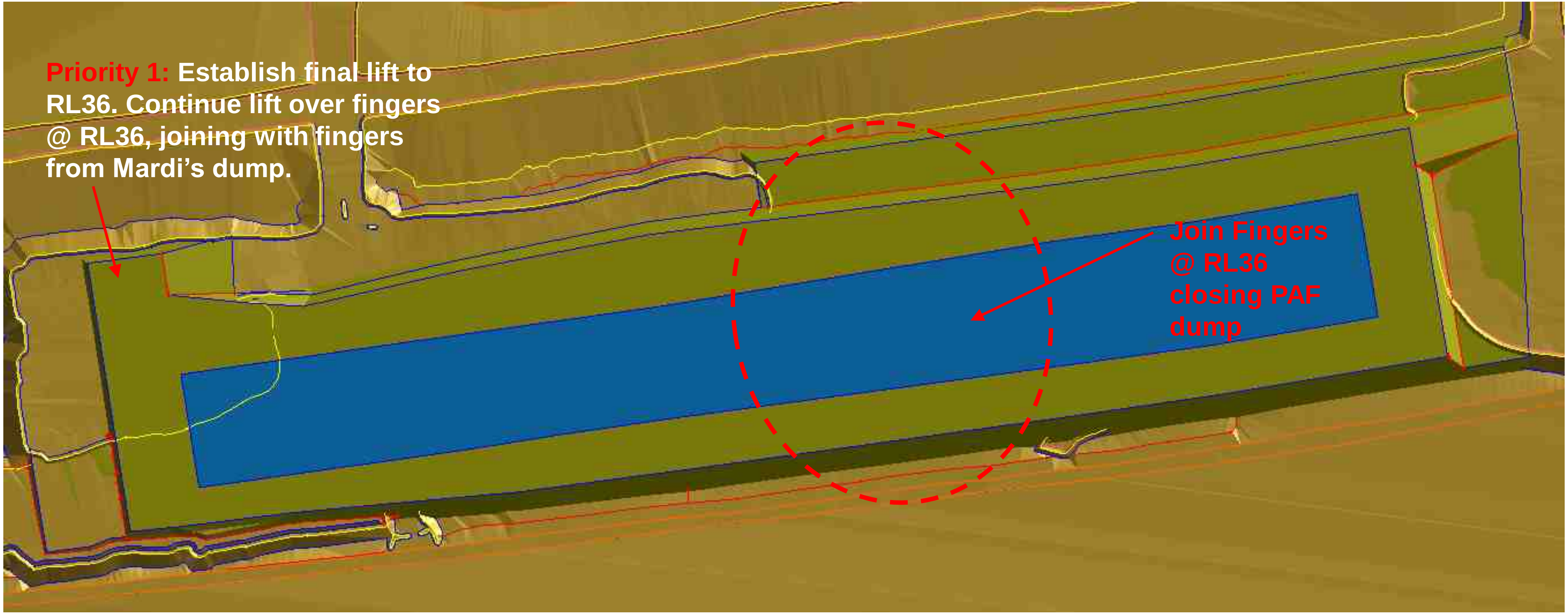
FE WRD PAF Cell Stage 2



Construction volume:
- Sesame St: 211,950 bcm
- Mardi's: 210,700 bcm

Cell Holding Capacity:
- Sesame St: 53,200 bcm
- Mardi's: 89,000 bcm

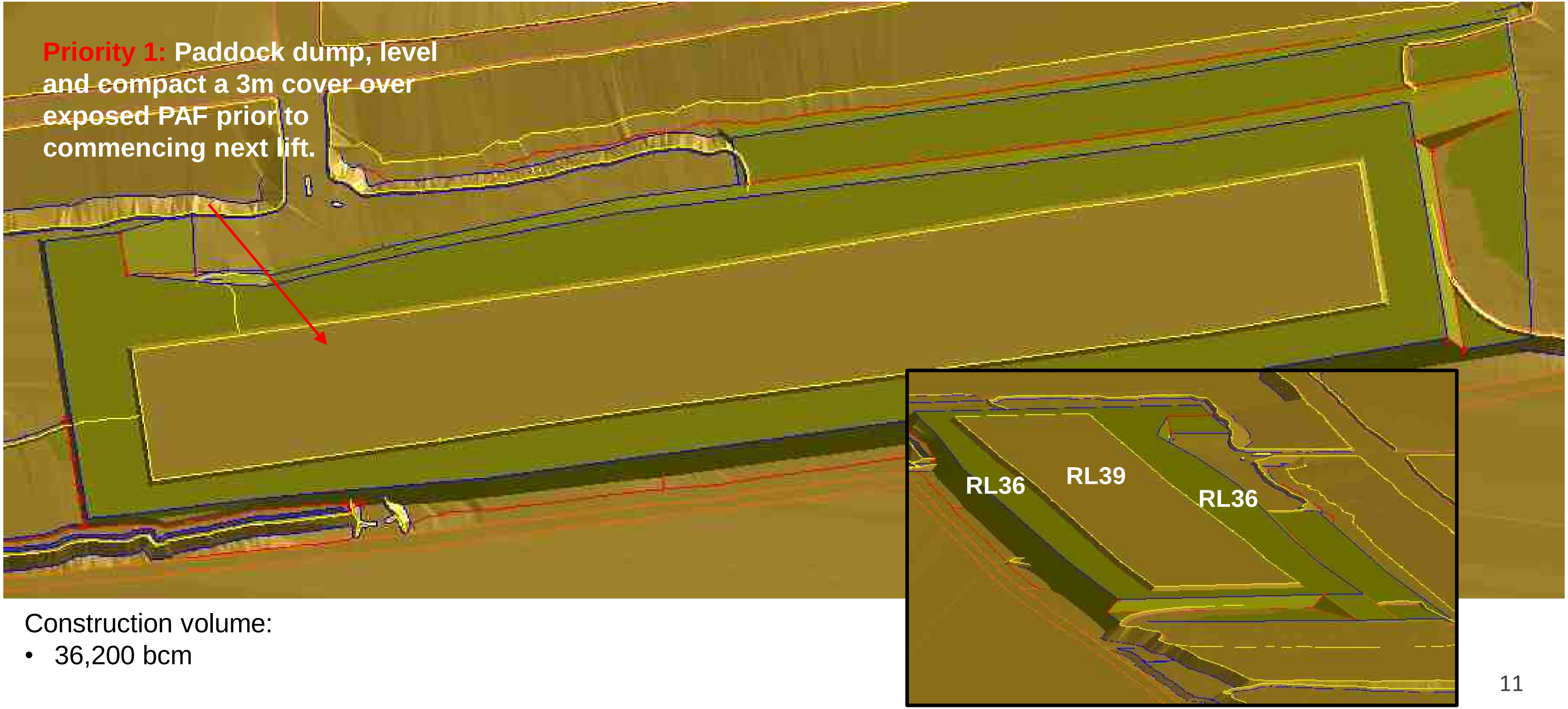
FE WRD PAF Cell Stage 3



Construction volume:
- 475,200 bcm

Cell Holding Capacity:
- 754,900

FE WRD PAF Cell Stage 4



Construction volume:

- 36,200 bcm

Appendix B: Independent Technical Review: Amanzi Consulting, 2019.

The following documents are included:

Appointment of independent technical reviewer RBIOM (EPBC 2012/6242)

Pendragon Environmental Solutions Response to Technical Review

Our Reference: pes19017_nathan river resources wd\response letter to peer review.docx

Your Reference:

pendragon environmental solutions
ABN: 92 147 485 416

Leaders in Environmental Practice

29 November 2019

METServe
PO Box 306
Fortitude Valley QLD 4006

For Attention: Jim Barker

Dear Jim

Independent Peer Review on 2019 NRR AMDMP

This review provides an independent assessment of the Pendragon Environmental Solutions (PES) 2019 Acid Mine Drainage Management Plan September 2019 (AMDMP) for the Nathan River Resources (NRR) Roper Bar Iron Ore Mine, Northern Territory. The review, undertaken by Dave Salmon (Amanzi Consulting), focused on the consistency of the AMDMP with the Australian Government Preventing Acid and Metalliferous Drainage 2016 Handbook (The Handbook); specifically, Sections 4,6,7,9 and Appendix 1.

We have pleasure in providing the following responses, and particularly how the issues/gaps in the AMDMP were addressed.

We trust that the response will meet with your approval. Please do not hesitate to contact us should you have any queries and/or require additional information.

Yours sincerely
Pendragon Environmental Solutions

Carel van der Westhuizen ***(MSc Hydrogeol, CEnvP SC, AffilIEAust, MEIANZ, MAIG, MALGA)***
Principal Hydrogeologist and Site Contamination Specialist

Peer Review	Response
2.1 The Purpose of the AMDMP: This AMDMP has been developed because the Roper Bar Mine will recommence mining in 2019 – 2020 after being under Care and Maintenance (C&M) from 2014 to 2019. The AMDMP outlines geochemical activities for the proposed mining of 1 Mtpa of Direct Shipping Ore (DSO) from the existing F-East area, Pits FE1 and FE2. The mine plans to extract 150,000 t of DSO blasted during previous mining operations and left in pit while the mine was in a C&M phase.	Noted; no changes required.
2.2 The Scope of the AMDMP The scope of the AMDMP required the update of the AMD risk and management plan (PES 2013) in respect to the; ▪ Development of the mine. ▪ Waste storage that has occurred on site. ▪ PAF quantities to be extracted 2019-2020 and the risks associated with this extraction. ▪ Mining material sampling requirements. ▪ AMD management requirements. This scope does not cover all the topics in the Checklist.	Noted; AMDMP was amended/restructured to aid future audits/peer reviews and to comply with the Checklist which is included in the AMDMP.
2.3 History Two previous AMD Management Plans have been developed for the Roper Bar Mine including: ▪ PES (2013), which covers AMD management during the project development and the first phase of mining from 2013 to September 2014. This work was subject to independent review. ▪ GHD (2015), which covers AMD management while Roper Bar was under Care and Maintenance (C&M) from 2015 to 2018. These plans were informed by various reports on AMD investigations and test work. Previous work is summarised in Table 1.2 of the AMDMP. All AMD documents produced prior to the latest AMDMP, followed guidance in the Australian Government Preventing Acid and Metalliferous Drainage 2007 Handbook and were reviewed for consistency against these guidelines.	Noted, no changes required.
2.4 AMDMP Format: Table 2.2 A tabulated format is used for the AMDMP (Table 2.2 in the AMDMP report), which is very useful for simplifying and summarising the plan. It addresses topics in the Handbook and the Checklist. However, it does not cover all sections and topics contained in the Checklist. Information on items in Section 9, and in Appendix 1 of the Checklist, are absent in the AMDMP.	Table 2.2 was amended/restructured to follow the sequence indicated in the Checklist and text was amended to be concise and clear.

Peer Review	Response
The information provided in AMDMP Table 2.2 does not follow the sequence in the Checklist. Some of the information provided in Table 2.2 is not concise and is unclear. This makes the tabulated format less easy to use. Information within Table 2.2 should be in a condensed form for practical effectiveness. An example of unclear information is the 3rd paragraph of the last section entitled Contingency Planning.	
2.5 AMD Risk and Management There is a low to medium risk of acid mine drainage development. Volumes of Potentially Acid Forming (PAF) material at Roper Bar are small and can be stored in containment cells within the waste rock dump. AMD risk assessment findings and mitigation measures to be implemented to reduce or minimise the risks are summarised in Table 2.1 of the AMDMP. There is potential to misinterpret design control measures and the operational management measures given in Table 2.1. For example, an operational management measure stated is “Selective materials handling and placement using mine schedule and geochemical modelling”. This is a combination of operational management measures and control measures. Selective handling and placement are the control measures; mine scheduling and geochemical modelling are the management measures. A review of the items in Table 2.1 is suggested to ensure they are in the correct cell. The AMDMP outlines the on-going assessment of the risk of AMD during mining. This will be done by identifying PAF material using on-site X Ray Fluorescence (XRF) analysis to measure the percentage (%) Total Sulfur (TS) in samples taken during grade control drilling. This review agrees with this approach. Geochemical test work has characterised ore and waste materials. Results are recorded in previous reports (PES 2013 and GHD 2015). Sufficient data has been produced to enable TS levels to be used to define PAF materials with confidence. The AMDMP outlines ongoing and additional geochemical test work needed and includes: 2.5.1 TS assessment to define and confirm potential PAF volumes during mining in 2019 and 2020. This is essential test work to produce data to ensure mining waste is handled and placed correctly. 2.5.2 Static testing for Sulfate-Sulfur and Chromium Reducible Sulfur to understand the type of pyritic sulfur in the weathered waste material. Samples numbers proposed for each weathered waste unit are 75 KYM, 140 MSM and 27 SIM samples. The AMDMP recommends this testing, but a clear commitment to this work with a sampling and testing schedule is needed. 2.5.3 An additional five (5) leach columns, to provide information on ore units (DSO, BDSO, DMSO, SIDOO, LDO). 2.5.4 Leach column testing of fresh and weathered KYM, SIM and MSM and waste (WST) material, because the existing six (6) columns are not representative of the three (3) main geological units on site. Whether this suggested kinetic testing of waste will involve new columns or replacement of existing columns is unclear.	Table 2.1 was amended and restructured. NRR gave clear commitments to finance and undertake further testing during the 2019-2020 Mine Plan. The original kinetic leach columns were damaged by fire and have not been monitored since the mine was placed in administration. Consequently, new columns will be installed when mining recommences. NRR has a preference for leach columns. The option of undertaking laboratory oxygen consumption testing will no longer be undertaken. The revised monitoring program is detailed in Section 9c of Table 2.2. The Mine Management Plan covering site works to remove redundant infrastructure and material stockpiles during Care and Maintenance and before mining recommences will have no impact on the level of AMD risk. PAF materials and exposed waste rock were covered as part of the Care and Maintenance Program.

Peer Review	Response
2.5.5 The AMDMP commits to additional kinetic geochemical data collection. However, there is no certainty on the methods to be employed, or explanation of why uncertainty exists. An "either/or" statement is given for column leach and oxygen consumption testing. This review could not assess or provide opinion on the appropriateness of the option to do oxygen consumption tests instead of leach columns because the AMDMP has not summarised previous work results nor does it provide the status and the results of recent test work. If test work has not been continued since the previous mining operations or there are mining units that require testing it will be necessary to do column leach tests to align with the guidelines. 2.5.6 Application of acid buffering characteristic curves (ABCC) to determine availability of neutralising materials in the main waste lithologies. 2.5.7 Australian Standard Leaching Procedure (ASLP) test work to assess the metal leaching potential of the KYM, SIM and MSM geological units. 2.5.8 ASLP results have to be validated against column leach test results. The AMDMP expressing uncertainty on whether the additional column leach tests will be undertaken. Assessment of the long term AMD risks should be ongoing. The uncertainty, noted in point 2.5.5 above, about test methods to be applied should be addressed to align the AMDMP with the Handbook and Checklist. Risks of AMD impacts have been assessed using a Source-Pathway-Receptor analysis (GHD, 2015), which is leading practice methodology. Existing PAF cell capacity is estimated to be 135,000 t. This capacity will accommodate the estimated PAF waste that will be produced during 2019 – 2020 mining operations. Reference is made to another Mine Management Plan covering site works to remove redundant infrastructure and material stockpiles. Impacts of these actions, if any, to the level of AMD risk and its management are not indicated in the AMDMP.	
2.6 Gaps in Information Detailed information on the gaps and inconsistencies identified in this review are provided in Table 1 (the completed Checklist). No quantity, flow or quality data or information is given for surface water, groundwater, onsite water collection, in-pit water, water storage facilities, and seepage water – input or from the WRD and stockpiles or the stockpile pads. There is no information provided on changes, if any, in monitoring that may have occurred over time as the mine moved from the project phase to the operational phase, from the operational phase to the care and maintenance phase, and during recommissioning to an operating mine. A section within the AMDMP provides a list of definitions of some technical terms and abbreviations. A number of acronyms occurring in Table 2.2 are not defined in the list. The AMDMP does not indicate if the blasted DSO material in-pit showed signs of AMD or whether the planned extraction of it will reduce the risk of AMD development. Blasting and breaking of material increases the area of exposed faces to oxygen and moisture. This can lead to conditions that can enhance AMD generation. In-pit water quality test results would indicate AMD generation.	The Table 1 Checklist was used to address the gaps and inconsistencies identified in the review. Surface and ground water quality were addressed in Section 9c of Table 2.2. No changes in monitoring over time as the mine moved from the project phase to the operational phase, from the operational phase to the care and maintenance phase, were recorded other than monitoring of the kinetic leach columns that ceased. The mine has not been recommissioned yet. The abbreviations and definitions were updated. The blasted DSO material in-pit is flooded and monthly inspections indicated that the pits and WRD show no signs of AMD impacts and in-pit water quality and the water quality in sediment/containment dams did not deteriorate other than the effects of evaporation. A conceptual site (source-pathway-receptor) and block models were added to the AMDMP.

Peer Review	Response
No block model or AMD site model was provided in the AMDMP. No risk assessment model – Source-Pathway-Receptor model - was provided in the AMDMP.	
2.7 Other Comments The AMDMP focuses on early detection of the risk of AMD and the management measures to prevent or minimise AMD development. AMD assessment and prevention management measures follow leading practice in approaches, methods, and procedures and reduce the need for AMD control and treatment. The AMDMP outlines geochemical activities that address the 2019 and 2020 mining. It may be inferred that this approach involved consultation between the AMD researchers and the mine planners and mine geologists. This is evidenced by the production of Standard Operating Procedures: Field Tests in August 2019, which is included as Appendix C of the AMDMP. TS assessment to define and confirm potential PAF volumes during mining in 2019 and 2020, is an appropriate geochemical test regime to classify mining waste to enable handling and storage to prevent or reduce AMD. PAF material handling and containment have been implemented. Diagrammatic representations of PAF cell design are included in Appendix A of the AMDMP. The design is aligned to the Handbook. The AMDMP does not clearly demonstrate sequential development of AMD test work. Differences between AMD Management Plans, the changes, over time, in investigations, the numbers of samples and analytic methods employed, the incremental increase in samples taken, analysed and analytical results achieved and what these mean to future test work and AMD management requirements are absent.	Noted. The restructure and amendment of Table 2.2 include sequential development of AMD test work, numbers of samples, analytical and assessment methodologies and outcomes. The entire database was considered in developing Section 9c Monitoring of AMD in Table 2.2. The differences between the AMD Management Plans pertain to their target i.e. operations versus care and maintenance; however, the approaches were duly considered in preparation of the management requirements for the AMDMP for the 2019-2020 Mine Plan.
3. Consistency between AMDMP content and the Checklist requirements The AMDMP was compared to the Handbook guidelines and Checklist Sections 4, 6, 7, 9 and Appendix 1. This review found the content of the AMDMP varies in its consistency with the Handbook and the DPIR Checklist. The detail of the differences are given in the completed Checklist (Section 4, Table 1, of this review) and are summarised as follows; • Topic 4 (Acid mine drainage characterisation and prediction) has been addressed according to the guidelines in the Handbook and the Checklist. • Topic 6 (Managing Sulfidic materials to prevent AMD) has been addressed according to the guidelines in the Handbook and the Checklist. • Topic 7 (AMD treatment) is, at this stage of mine development, not required because AMD prevention measures are effective. • Topic 9 (Performance evaluation and monitoring) has some gaps in information. • Appendix 1 (Table A.1 Elements of an AMD monitoring program) has not been addressed.	Noted; refer earlier responses with regard to data gaps and inconsistencies. Appendix 1 (Table A.1 Elements of an AMD monitoring program) has now been addressed.

Peer Review	Response
Inconsistencies between the AMDMP and the Handbook and Checklist are mainly due to the AMDMP omitting information and data that is available in other AMD documents. Where data or information needs updating, the AMDMP has identified the work requirement to provide the required data and information.	
5. Recommendations and Closing Comments The following recommendations are made on the basis of this review and to ensure the AMDMP is consistent with the Checklist, the Handbook and Appendix 1 Table A.1 – Elements of an AMD monitoring program. The AMDMP should clearly demonstrate sequential development and the changes over time between previous AMD Management Plans and investigations. To this end Section 1.4 entitled "Status Quo" could include the status quo, in summary, of AMD test work and results, and of the water quantity and quality monitoring. The water quality results can be used to indicate effectiveness of the AMD management measures implemented and can be used to complete Appendix 1 of the Checklist. Throughout this review where summarised data and information are recommended it is suggested that Tables be used, if appropriate and practical. The AMDMP should provide substantive evidence, in a highly summarised format, that it meets the Handbook guidelines and Checklist requirements. Summarised data and information about; • The AMD testing methods used • The numbers of samples taken, tested and analysed, per test method, and a summary of the analytical results • A record of changes and differences, in this data and information, between consecutive management plans and investigations • The Total S results and material characterisation • Planned geochemical testing to fill data gaps. Whether the on-site XRF has been purchased and is used is unclear. If an on-site XRF is being used the number of samples analysed and results produced should be quoted. The numbers and results of samples checked by an outside laboratory to determine the precision of the on-site XRF should be stated. The structure of AMDMP Table 2.2 should be formatted to; • Include all Checklist topics. • Follow the Checklist sequential layout of topics and items. • Provide data and information for Appendix 1 of the Checklist. Re-structuring the Table in this way will; • Assist communication with the regulator • Expedite the review of future AMD management plans by the DoE	Noted. We are of the opinion that the restructured and amended AMDMP is now consistent with the Checklist, the Handbook and Appendix 1 Table A.1 – Elements of an AMD monitoring program as recommended by the peer review. Reference should be made to the responses above. The NRR procedure for data storage, evaluation and reporting was included in Section 9c of the AMDMP. NRR is committed to make financial provision for ongoing AMD monitoring, water monitoring and geochemical test as part of their operation and mine closure budgets and provisions.

Peer Review	Response
• Simplify the updating of the AMDMP • Reduce the independent reviewer AMDMP review time. The AMDMP identifies the need for additional geochemical test work, but only suggests rather than commits to the tests that will be done. The test work can be prioritised, scheduled and planned to fit in with the mining timeline, and this information included in the AMDMP. Firm commitment on the test work methods to be used can be given and can be based on the previous test work results. A summary of previous and most up to date test work results provide evidence for the choice of test work method. This summary can be included in the AMDMP. Additional static test work is suggested in the AMDMP (assessment of sulfate-sulfur and chromium reducible sulfur), but a clear commitment to this work with a sampling and testing schedule is needed. The AMDMP states that the existing columns predominantly test KYM material. It also suggests that five (5) additional columns are needed to expand testing to include all ore types and the new geological classification of waste materials into KYM, SIM and MSM and waste (WST). The number of columns suggested and the number of different materials to be tested differ. Explanation of this difference is required. The construction of planned leach columns (material per column) should be included in the AMDMP. The usefulness of the previous 6 columns needs to be stated and this statement based on up to date test results. If test work has not been continued then the reasons for this need to be given. Confirmation of the chosen kinetic testing methods is required. The uncertainty on the way forward on test methods, amplified by the statement "if undertaken" (in regard to doing column leach tests) needs to be removed by commitment to specific tests to be made in the AMDMP. The AMDMP should contain summarised quantity and quality monitoring results for surface water, groundwater and any other mine affected water such as, in-pit, in collection trenches, seepages, in-pit and from the WRD and stockpiles or stockpile pads. Key analytes in water monitoring, which reflect AMD status e.g. pH, EC, SO4, specific indicator metals, should be noted. Comment on salinity should be given as this aspect is part of the AMD continuum. Trends in the water monitoring data, such as deterioration in water quality and decrease or increase in flows, should be identified. Changes that can be ascribed to the effectiveness of AMD management measures should be noted. Other information needed to ensure consistency with the Checklist includes: • Information about data storage, evaluation and reporting. • A copy of the AMD conceptual model. • Diagrams of the Source-Pathway-Receptor analysis can be provided in the AMDMP together with a copy of the Block Model. • A diagram of the construction method of the WRD. This is would be in addition to the PAF cell construction diagrams that were proved in Appendix A of the AMDMP. • Information on financial assurance and technical provisioning (required in Section 9 of the Handbook)	

Peer Review	Response
A financial provision for ongoing AMD monitoring, water monitoring and geochemical test work would align the AMDMP with the Checklist. Comment should be given on whether the site works that were used to remove redundant infrastructure and material stockpiles impacted the level of AMD risk and the way this risk is managed. Review and edit the content in Table 2.2 to ensure it is clear and concise. Avoid cutting and pasting text from previous reports where doing so causes a reduction in the clarity of information in the Table. Expand the Abbreviations List to include all technical and other acronym definitions to prevent confusion and to assist the understanding and reading of the AMDMP. Regular review of the AMDMP will enhance continuous improvement in AMD management.	

TECHNICAL REPORT

Technical Review: AMDMP for the Roper Bar Mine, Northern Territory

Report prepared for

Nathan River Resources and METServe

AMANZI CONSULTING

TECHNICAL REPORT

Review of the AMDMP for NRR Roper Bar Mine

Report prepared for

Nathan River Resources and METServe

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AMDMP_ Review _NRRRoper Bar _Final (MET00266434-006)_(AC2019-010)	**Final**	**Jim Barker METServe**	**20-11-2019**

Table of Contents

Tables

Summary

The content of the Acid Mine Drainage Management Plan September 2019 (AMDMP) varies in its consistency with the Australian Government Acid Mine and Metalliferous Drainage Handbook 2016, and the Commonwealth Department of Environment (DoE) Checklist (the Checklist).

Acid mine drainage characterisation and prediction and the management of mined ore and mining waste materials have been addressed at Roper Bar Mine.

AMD treatment is, at this stage of mine development, not required because prevention measures are effective.

AMD performance evaluation and monitoring has some information gaps when compared to the Checklist.

Appendix 1 (Table A.1-Elements of an AMD monitoring program) of the Handbook has not been addressed in the AMDMP. The DPIR included Appendix 1 as part of the Checklist.

The AMDMP outlines geochemical investigations for mining activities planned during 2019 and 2020.

The approaches, methods and procedures followed in the AMDMP are leading practice.

The use of Total Sulfur for classifying material samples taken from grade control boreholes are appropriate during mining operations to confirm waste placement.

Assessment of the long term AMD risks should be ongoing. There is uncertainty, expressed in the AMDMP, on what methods will be applied. This issue has to be to be addressed to align the AMDMP with the Handbook and Checklist.

Recommendations are provided to update the AMDMP to make it consistent with the Handbook and Checklist.

AMANZI CONSULTING
ABN 79 608 467 778

1. Introduction

This review provides an independent assessment of the Pendragon Environmental Solutions (PES) 2019 Acid Mine Drainage Management Plan September 2019 (AMDMP) for the Nathan River Resources (NRR) Roper Bar Iron Ore Mine, Northern Territory.

1.1 Scope of work

Mr Dave Moss (General Manager of Mining and Energy Technical Services Pty Ltd (METServe), working on behalf of NRR, requested Dave Salmon (Amanzi Consulting) to perform the review. The review focuses on the consistency of the AMDMP with the Australian Government Preventing Acid and Metalliferous Drainage 2016 Handbook (The Handbook); specifically, Sections 4,6,7,9 and Appendix 1.

1.2 Review methodology

The review of the AMDMP was completed according to:

- The Amanzi Consulting proposal (September 2019) to provide an independent review of the AMDMP.
- A subsequent email; sent by METServe on behalf of NRR, to Amanzi Consulting; requested completion of a Checklist, produced by the Commonwealth Department of Environment (DoE).

The Checklist was completed by following the DoE directives contained in the copy of the Checklist supplied to Amanzi Consulting. The directives required;

- *An outline of how the* AMDMP *document is consistent with the different sections within the Handbook.*
- *An explanation of why guidance in the Handbook is not relevant to the Roper Bar Project if the* AMDMP *document does not address or is inconsistent with the respective section of the Handbook and how that inconsistency will improve PAF management (and give references etc to substantiate that claim).*
- *Comment on Where and How the Topics in Sections 4,6,7,9 and Appendix 1 of the Handbook are addressed within the* AMDMP *document.*

The completed Checklist is provided in Section 4 of this review report.

2. Comments

2.1 The purpose of the AMDMP

This AMDMP has been developed because the Roper Bar Mine will recommence mining in 2019 – 2020 after being under Care and Maintenance (C&M) from 2014 to 2019.

The AMDMP outlines geochemical activities for the proposed mining of 1 Mtpa of Direct Shipping Ore (DSO) from the existing F-East area, Pits FE1 and FE2. The mine plans to extract 150,000 t of DSO blasted during previous mining operations and left in pit while the mine was in a C&M phase.

2.2 The Scope of the AMDMP

The scope of the AMDMP required the update of the AMD risk and management plan (PES 2013) in respect to the;

- Development of the mine
- Waste storage that has occurred on site
- PAF quantities to be extracted 2019-2020 and the risks associated with this extraction
- Mining material sampling requirements
- AMD management requirements.

This scope does not cover all the topics in the Checklist.

2.3 History

Two previous AMD Management Plans have been developed for the Roper Bar Mine including:

- PES (2013), which covers AMD management during the project development and the first phase of mining from 2013 to September 2014. This work was subject to independent review.
- GHD (2015), which covers AMD management while Roper Bar was under Care and Maintenance (C&M) from 2015 to 2018.

These plans were informed by various reports on AMD investigations and test work.

Previous work is summarised in Table 1.2 of the AMDMP.

All AMD documents produced prior to the latest AMDMP, followed guidance in the Australian Government Preventing Acid and Metalliferous Drainage 2007 Handbook and were reviewed for consistency against these guidelines.

2.4 AMDMP format: Table 2.2

A tabulated format is used for the AMDMP (Table 2.2 in the AMDMP report), which is very useful for simplifying and summarising the plan. It addresses topics in the Handbook and the Checklist. However, it does not cover all sections and topics contained in the Checklist. Information on items in Section 9, and in Appendix 1 of the Checklist, are absent in the AMDMP.

The information provided in AMDMP Table 2.2 does not follow the sequence in the Checklist.

Some of the information provided in Table 2.2 is not concise and is unclear. This makes the tabulated format less easy to use. Information within Table 2.2 should be in a condensed form for practical effectiveness. An example of unclear information is the 3rd paragraph of the last section entitled Contingency Planning.

2.5 AMD Risk and management

There is a low to medium risk of acid mine drainage development. Volumes of Potentially Acid Forming (PAF) material at Roper Bar are small and can be stored in containment cells within the waste rock dump.

AMD risk assessment findings and mitigation measures to be implemented to reduce or minimise the risks are summarised in Table 2.1 of the AMDMP.

There is potential to misinterpret design control measures and the operational management measures given in Table 2.1. For example, an operational management measure stated is *"Selective materials handling and placement using mine schedule and geochemical modelling".* This is a combination of operational management measures and control measures. Selective handling and placement are the control measures; mine scheduling and geochemical modelling are the management measures. A review of the items in Table 2.1 is suggested to ensure they are in the correct cell.

The AMDMP outlines the on-going assessment of the risk of AMD during mining. This will be done by identifying PAF material using on-site X Ray Fluorescence (XRF) analysis to measure the percentage (%) Total Sulfur (TS) in samples taken during grade control drilling. This review agrees with this approach.

Geochemical test work has characterised ore and waste materials. Results are recorded in previous reports (PES 2013 and GHD 2015). Sufficient data has been produced to enable TS levels to be used to define PAF materials with confidence.

The AMDMP outlines ongoing and additional geochemical test work needed and includes:

2.5.1 TS assessment to define and confirm potential PAF volumes during mining in 2019 and 2020. This is essential test work to produce data to ensure mining waste is handled and placed correctly.

2.5.2 Static testing for Sulfate-Sulfur and Chromium Reducible Sulfur to understand the type of pyritic sulfur in the weathered waste material. Samples numbers proposed for each weathered waste unit are 75 KYM, 140 MSM and 27 SIM samples. The AMDMP recommends this testing, but a clear commitment to this work with a sampling and testing schedule is needed.

2.5.3 An additional five (5) leach columns, to provide information on ore units (DSO, BDSO, DMSO, SIDOO, LDO).

2.5.4 Leach column testing of fresh and weathered KYM, SIM and MSM and waste (WST) material, because the existing six (6) columns are not representative of the three (3) main geological units on site. Whether this suggested kinetic testing of waste will involve new columns or replacement of existing columns is unclear.

2.5.5 The AMDMP commits to additional kinetic geochemical data collection. However, there is no certainty on the methods to be employed, or explanation of why uncertainty exists. An "either/or" statement is given for column leach and oxygen consumption testing. This review could not assess or provide opinion on the appropriateness of the option to do oxygen consumption tests instead of leach columns because the AMDMP has not summarised previous work results nor does it provide the status and the results of recent test work. If test work has not been continued since the previous mining operations or there are mining units that require testing it will be necessary to do column leach tests to align with the guidelines.

2.5.6 Application of acid buffering characteristic curves (ABCC) to determine availability of neutralising materials in the main waste lithologies.

2.5.7 Australian Standard Leaching Procedure (ASLP) test work to assess the metal leaching potential of the KYM, SIM and MSM geological units.

2.5.8 ASLP results have to be validated against column leach test results. The AMDMP expressing uncertainty on whether the additional column leach tests will be undertaken.

Assessment of the long term AMD risks should be ongoing. The uncertainty, noted in point 2.5.5 above, about test methods to be applied should be addressed to align the AMDMP with the Handbook and Checklist.

Risks of AMD impacts have been assessed using a Source-Pathway-Receptor analysis (GHD, 2015), which is leading practice methodology.

Existing PAF cell capacity is estimated to be 135,000 t. This capacity will accommodate the estimated PAF waste that will be produced during 2019 – 2020 mining operations.

Reference is made to another Mine Management Plan covering site works to remove redundant infrastructure and material stockpiles. Impacts of these actions, if any, to the level of AMD risk and its management are not indicated in the AMDMP.

2.6 Gaps in information

Detailed information on the gaps and inconsistencies identified in this review are provided in Table 1 (the completed Checklist).

No quantity, flow or quality data or information is given for surface water, groundwater, on-site water collection, in-pit water, water storage facilities, and seepage water – inpit or from the WRD and stockpiles or the stockpile pads.

There is no information provided on changes, if any, in monitoring that may have occurred over time as the mine moved from the project phase to the operational phase, from the operational phase to the care and maintenance phase, and during recommissioning to an operating mine.

A section within the AMDMP provides a list of definitions of some technical terms and abbreviations. A number of acronyms occurring in Table 2.2 are not defined in the list, which limits the practical use of the Table.

The AMDMP does not indicate if the blasted DSO material in-pit showed signs of AMD or whether the planned extraction of it will reduce the risk of AMD development. Blasting and breaking of material increases the area of exposed faces to oxygen and moisture. This can lead to conditions that can enhance AMD generation. In-pit water quality test results would indicate AMD generation.

No block model or AMD site model was provided in the AMDMP.

No risk assessment model – Source-Pathway-Receptor model - was provided in the AMDMP.

2.7 Other comments

The AMDMP focuses on early detection of the risk of AMD and the management measures to prevent or minimise AMD development. AMD assessment and prevention management measures follow leading practice in approaches, methods, and procedures and reduce the need for AMD control and treatment.

The AMDMP outlines geochemical activities that address the 2019 and 2020 mining. It may be inferred that this approach involved consultation between the AMD researchers and the mine planners and mine geologists. This is evidenced by the production of Standard Operating Procedures: Field Tests in August 2019, which is included as Appendix C of the AMDMP.

TS assessment to define and confirm potential PAF volumes during mining in 2019 and 2020, is an appropriate geochemical test regime to classify mining waste to enable handling and storage to prevent or reduce AMD.

PAF material handling and containment have been implemented. Diagrammatic representations of PAF cell design are included in Appendix A of the AMDMP. The design is aligned to the Handbook.

The AMDMP does not clearly demonstrate sequential development of AMD test work. Differences between AMD Management Plans, the changes, over time, in investigations, the numbers of samples and analytic methods employed, the incremental increase in samples taken, analysed and analytical results achieved and what these mean to future test work and AMD management requirements are absent.

3. Consistency between AMDMP content and the Checklist requirements

The AMDMP was compared to the Handbook guidelines and Checklist Sections 4, 6, 7, 9 and Appendix 1.

This review found the content of the AMDMP varies in its consistency with the Handbook and the DPIR Checklist. The detail of the differences are given in the completed Checklist (Section 4, Table 1, of this review) and are summarised as follows;

- Topic 4 (Acid mine drainage characterisation and prediction) has been addressed according to the guidelines in the Handbook and the Checklist.

- Topic 6 (Managing Sulfidic materials to prevent AMD) has been addressed according to the guidelines in the Handbook and the Checklist.
- Topic 7 (AMD treatment) is, at this stage of mine development, not required because AMD prevention measures are effective.
- Topic 9 (Performance evaluation and monitoring) has some gaps in information.
- Appendix 1 (Table A.1 Elements of an AMD monitoring program) has not been addressed.

Inconsistencies between the AMDMP and the Handbook and Checklist are mainly due to the AMDMP omitting information and data that is available in other AMD documents.

Where data or information needs updating, the AMDMP has identified the work requirement to provide the required data and information.

4. The Checklist

This Checklist is used to assess the consistency of the AMDMP for the NRR Roper Bar Iron Ore Mine with the Australian Government's Preventing Acid and Metalliferous Drainage (September 2016) Handbook. The Checklist was supplied to Amanzi Consulting by METServe.

The guidance supplied by the DoE to complete the Checklist required that for each row/item/section (Topics 4,6,7,9 and Appendix 1) the following actions are required.

- Outline how the AMDMP is consistent with the Handbook;
- If the AMDMP does not address/is inconsistent with the respective section of the Handbook please explain why guidance in the Handbook is not relevant to the Roper Bar Project and how that inconsistency will improve PAF management (and give references etc to substantiate that claim).

Table 1: The Checklist

Handbook 2016 topics	Where/how addressed in the AMDMP 2019
9a Sampling and analysis procedures that will be employed to identify potential acid forming (PAF) materials.	
Sampling for characterisation. ***4.2.1 Overview***	**Where** AMDMP Table 1.2 (References: GHD 2015, PES 2013) **How** Definition of main geological materials and lithologies and mining material into ore and waste based on Fe content. Using multiple test methods with increasingly detailed sampling and materials characterisation. Geochemical classification of mining materials into PAF, NAF, UC, and AC and assessing risk of AMD using Source-Pathway-Receptor analysis. Specialist AMD consultants have been used for the work. Characterisation was done to meet the Environmental Protection Agency (EPA) conditions for approval of the Environmental Impact Statement (EIS). Later investigations and reports addressed SEWPaC requirements that included: • Sampling and analysis procedures that will be employed to identify PAF materials.

	• Design details and management strategies of proposed encapsulation beds (cells), waste rock dumps, drainage systems, sediment traps, seepage diversion barriers, collection ponds and embankments. • A strategy for the ongoing monitoring of PAF material, including threshold trigger levels and mitigation responses. Earlier work that was performed, followed Australian Government AMD Guidelines in the 2007 Handbook and included: • Static geochemistry test work on several hundred samples with sufficient samples to populate the geological block model with reliable distribution of NAPP data on the ore and the waste streams: the mining discards, and pit backfill overburden material. • Kinetic tests for 1 to 2 representative samples for key lithologies and waste materials specifically those identified as PAF or UC. Geochemical Test Work involved: • Static (ABA) testing: including maximum potential acidity (MPA), Net Potential Ratio (NPR), and Net Acid Production Potential (NAPP). • Kinetic testing: column leach construction and analyses and ALPS. • Mineralogical Assessment: by XRD, XRF and EDS. • Metal assessment: using geochemical abundance index (GAI). Enough sampling has been completed to establish a block model and inform future sampling protocols, analytical needs and ongoing test work, to confirm findings and direct adjustments to risk assessment and management plans (AMDMP Table 2.2 p19).
4.2.2 In-place mine materials	**Where** AMDMP Table 2 (References: EcOz 2012, PES 2013, and GHD 2015) **How** Initial work prior to mining established material characteristics. Two hundred and four (204) samples from fifty-eight (58) exploration boreholes were sampled and analysed from various geological horizons and rock types found in mining areas: • Area E: East Pit and South Pit. • Area F: East Pit 1, East Pit 2, East Pit 3, and the West Pit. Samples were taken of the main lithologies including sandstones and sandstone oolites, (50% of the lithotypes in the area); siltstones, oolites, oolitic sandstone, and clays. This established the main geological units: • KYM- the Kyalla Siltstone Member. • MSM -the Moroak Sandstone Member. • SIM – the Sherwin Iron Member. Planned static testing sample numbers for the 2019 – 2020 mining plan (in Table 2.2 p19 of the AMDMP) include 75 KYM, 140 MSM and 27 SIM.
4.2.3 Existing exposed mine materials	**Where** AMDMP Section 1. Sub section 1.1 (Reference: GHD 2015). **How** The following mine materials are presently exposed: • Blasted DSO 135,000 t remaining from the first phase of mining prior to C&M phase. • Ore and overburden in pit faces. • Waste in waste rock dumps. • Materials exposed in stockpiles

	These materials were assessed by PES (2013).
Geochemical static tests ***4.3.1 Field Measurements***	**Where** Table 2.2 p19 **How** On-site XRF analysis for Total %S. Total S% defines PAF as >0.3%.
4.3.2 Mineralogical analysis	**Where** Reference EcOz 2012 and GHD 2015 **How** Early work involved: • Analysing fifty-six (56) samples using X-ray powder diffraction (XRD). • Forty-six (46) samples representing the principle waste rock streams were analysed by scanning electron microscopy (SEM) and energy dispersive X-ray spectrometer analysis (SEM-EDS) techniques. • Sulfur assessment was done by XRF analysis of fifty-one (51) laboratory analysed samples or field measurements.
4.3.3 Elemental composition	**Where** Reference: PES 2013 **How** Laboratory X-Ray Fluorescence (XRF) of 25,386 samples for Total S% and 25,387 samples for CaO and MgO. Other analytes included: Al_2O_3, Fe, Mn, Mo, P, SiO_2, TiO_2 and K_2O Hydrochemical leach testing of eighty-five (85) samples was performed using de-ionised water in accordance with the Australian Standard Leaching Procedures (ASLP). The results were plotted on Piper diagrams to classify leachate types.
4.3.4 Acid base account	**Where** AMDMP Table 2.2 p19 (Reference: EcOz 2012, PES 2013, and GHD 2015). **How** Two hundred and four (204) ABA and NAG samples of which one hundred and seventy-five (175) samples were applicable to the mine disturbance area i.e. within the KYM, MSM and SIM units. Static test work used to determine lithological characterisation and assessing the characteristics of the combination of these materials that will make up the WRD. A standard suite of analyses was performed using standard testing methods from an accredited laboratory (ALS). The acid base chemistry was determined for all waste materials by: • pH and EC of paste solutions. • Oxidation pH. • Total S and sulphate sulfur. • Assessing the Acid Neutralising Capacity (ANC) carbonate alkalinity (as CaCO3) and the Net–Acid Generation (NAG). • Calculating Maximum Potential Acidity (MPA), Net Acid Producing Potential (NAPP) and the Acid Potential Ratio (APR).

	In summary the geochemical static test work report includes: • Descriptions of methods used in the analysis. • Records of the initial characterisation results of most in-situ materials. • Records of the leachates chemistry from the waste material. • Assessment of the geological sequence to determine PAF, NAF or UC by lithology. • Identification of the potential sources of AMD in the East and West Pit waste rock dumps. • Provides an initial mine waste balance and a mine waste management option including the placement of PAF material within the dumps. • Document a risk assessment process and provide a risk assessment for the management of the waste
4.3.5 Net acid generation test	Yes, as above 4.3.4
4.3.6 Sulfur and carbon speciation	**Where** Additional assessment in AMDMP Table 2.2
4.3.7 Sample classification	**Where** AMDMP (Reference**s:** PES 2013 and GHD 2015.) **How** Mining material types are grouped according to iron content: • Mining waste (WST) is material with <30% Fe content and is subdivided into geological units KYM, SIM, MSM and sub-units of fresh and weather (oxidised) materials. • Ore types are defined by Fe content > 30% and include Direct Shipping Ore (DSO) >60%; Blended Direct Shipping Ore (BDSO) 54-60%; Dense Media Separation Ore (DMSO) 45-54%: Siderite Ore (SIDOO) 30-54% and LOI > 10%, and Low Grade Ore (LGO) both fresh and weathered. Materials and ores are classified according to the 2016 Handbook and other AMD standards and guidelines into; • Non Acid Forming (NAF). • Potentially Acid Forming (PAF). • Uncertain (UC material that cannot be definitively classified as PAF or NAF. • Acid consuming (AC). AMD characteristics of the different lithologies, including weathered (oxidised) and fresh lithological units, are classified according to Total Sulfur content, e.g. Low Sulfur <0.3% and High Sulfur >0.3%. Net Potential Ratio (NPR) sums Ca Mg oxides against Total S content (excluding sulfate sulfur). Net Acid Production Potential NAPP sums Ca Mg oxides against Total %S content (excluding sulfate sulfur). Total S % are conservative estimations as they exclude sulfate sulfur which may have neutralising sulfates. **How**

	The 2012 ABA Static test work results produced a general bulk geochemical characterisation adequate to inform need for kinetic tests. Characterisation at that time, as % of all samples tested: NAF 52%, PAF 34% and Uncertain 14%. Wet geochemical testing (see GHD Appendix A 3.4.1) used to establish simple NAF/PAF classification threshold and PAF in waste materials. NAPP testing showed low % PAF such that a PAF volumes can be estimated using total S% grade cut off of 0.3% This excludes CaO and MgO minerals, so this is a conservative estimate.
4.4 AMD block modelling and materials scheduling	**Where** Not detailed in AMDMP
4.5 Geochemical kinetic tests	**Where** AMDMP Table 2.2 p19 (References: PES 2013 GHD 2015) **How** Six (6) columns comprising mostly KYM weathered material and a dataset from November 2012 to May 2014. Latest results were not disclosed in the AMDMP. Kinetic testing is stated to have been performed on the basis of results of the AMD risk assessment, of conceptual waste rock dump designs, and the handling of PAF material during mining operations. AMDMP proposes five (5) additional columns to assess the ore stream DSO, BDSO, DMSO, SIDO, and LGO and to assess some WST (<30% total Fe) - fresh and weathered KYM, SIM, and MSM comprising low and high total sulfur <0.3% and >0.3% respectively.
4.5.1. Column leach and humidity cell tests	**Where** AMDMP Table 2.2 (References: PES 2013 and GHD 2015) **How** Previous assessments are described in PES (2013). Six (6) columns were established to assess mining waste materials. Five (5) “tons” (sic) of drill cuttings and pit samples of waste materials, were broken down to sizes of blasted broken waste, sieved and packed into six (6) separate columns (barrels). The columns were set up to account for; • Results of static testing, which showed PAF material dominantly occurs at 30 m depth below surface and to account • Mixing of PAF and NAF materials; a result of blasting. Two sets of columns, one set representing low sulfide spoil concentrations and the other set high sulfide concentrations after blasting. The sources and the combination of the materials used in the column are described in PES (2013). The results of the analyses confirmed the outcomes of the static testing for all columns except columns 4 and 6. • Columns 1 and 2 were confirmed as PAF. • Column 5 was UC. • Column 3 confirmed as NAF. • Columns 4 and 6 were found to be UC.

	The leachate qualities observed are indicative of spoil materials that have been naturally weathered. AMDMP suggests five (5) additional columns to bring the total to eleven (11) columns to expand testing to include all ore types and the new geological classification of waste materials KYM, SIM and MSM and waste (WST). Commitment to do the additional columns is not given. The statement “if undertaken” in regard to doing column leach tests is repeated in the AMDMP implying uncertainty on the way forward. The AMDMP offers the option of doing oxygen consumption tests instead of leach columns. This review could not assess or provide opinion on the appropriateness of either method because no results of any recent test work were given in the AMDMP. If test work has not been continued since the previous mining operations stopped then it will be necessary to do column leach kinetic testing to align with the guidelines. Test work suggested, but not committed to, includes; • Assessment of neutralising materials in the main lithologies using acid buffering characteristics curves (ABCC) • Australian Standard Leaching Procedure (ASLP) to understand metal leaching potential from the KYM, SIM and MSM waste materials. The results of these test have to be calibrated against column leach results. They have more limited value as stand-alone results, particularly in terms leaching characteristics when material is buried within the WRD.
4.5.2 Oxygen consumption tests	**Where** AMDMP Table 2.2 P 19 and Table 2.2 P 20. **How** Not previously performed. Plan will be done to determine pyrite oxidation rates for all geological units. Pyrite oxidation rates are slow 2.25E-11mol/m2/s (Table 1.2 AMDMP). There is no commitment to do these tests in the AMDMP, only a suggestion to do them and perhaps in place of the additional column leach tests (as noted in 4.5.1).
4.5.3 Oxygen penetration tests	These tests are primarily used in tailings facilities.
Scaling-up of laboratory test results ***4.6.1 Pilot-scale field tests***	Not performed prior to mining in 2013. Geochemical testing had been sufficient and rigorous enough to determine that PAF in small volumes can be handled in containment cells within the waste rock dump. The best field test is monitoring the existing WRD.
4.6.2 Large to full scale field tests	Not performed prior to mining Monitoring water from existing WRD and stockpiles is being planned.
Estimating and modelling pollutant generation and release rates ***4.7.1 Overview***	**Where** AMDMP Table 2.2 p20 **How** ASLP testing metal leaching potential from KYM, SIM, and MSM in addition to data from Kinetic Test Leach columns is suggested in the AMDMP.

	Conceptual site model based on Source-Pathway-Receptor analysis can assist in modelling and this analysis is given in GHD (2015).
4.7.2 AMD prediction using empirical test results	Acidity load is not given in the AMDMP
4.7.3 AMD prediction using computer models	Not reported in the AMDMP
9b. Design details and management strategies of proposed encapsulation beds, waste rock dumps, drainage systems, sediment traps, seepage diversion barriers, collection ponds and embankments;	
Management of waste rock dumps to minimise AMD ***6.1.1 General considerations***	**Where** AMDMP 2019 Section 1.4 p14, Table 2.1 and Appendix A **How** AMD and waste rock management strategy developed, and management measures identified and implemented. Summary of AMD risk assessment and mitigation measures outlined (Table 2.1). WRD base to be constructed of weathered impermeable NAF KYM and to be 2 metres (m) thick. WRD cap will be NAF MSM of 1.2 m thickness over which rock armour and soil of 0.5m thickness will be placed and profiled for erosion control and slope stabilisation. Proactive AMD source minimisation and prevention by: • WRD store and release cover system planned to inhibit oxygen and moisture ingress. • Paddock Dumping of waste material rather than End Dumping. End dumping creates more opportunity for oxidation. • Encapsulation of PAF in 100,000m^3 volume containment cells constructed of NAF KYM within the WRD. Containment cells to have 2.5m thick base and cover and 4m thick side cover (See Plan in Appendix A). • Planned pit backfilling of waste in future when pit space available. • Ongoing identification of AMD generating waste with PAF assessment on grade drilling drill samples. Backfilling in-pit can only commence as mining progresses extraction to the full depth of the resource (Table 2.2 Page 18). PAF material stored in PAF cells of and constructed in the WRD (Appendix A). GHD (2015) describes civils works to control AMD generation and control and contain water, including stormwater levees and ROM pad levees, sediment dams and temporary levee around F East pits and WRDs.
6.1.2 Conventional end-dumped WRDs	**Where** AMDMP **How**

	WRD main construction Paddock Dumping; not end dumping. End dumping of PAF into lined cells within the WRD will occur. Since containment cells are lined and have no direct outside contact with air, oxygen ingress and AMD production is minimised when compared to end tipping.
6.1.3 Oxidation rate and lag time to production of AMD	Not sighted in AMDMP. AMD production should be prevented by placing PAF in containment cells within the dump and in future, if PAF is backfilled into the pit.
6.1.4 Construction methods for WRDs to minimise AMD production	**Where** AMDMP Table 2.2 P18. (Reference: PES 2019, GHD 2015) Diagrams of containment cell and dump construction provided in the AMDMP Appendix A and also in GHD 2015. **How** Use of suitable construction materials: • NAF waste both weathered and fresh material stockpiled for future use as WRD encapsulation and capping material. • NAF weathered waste rock MSM stockpiled for use as WRD capping. • NAF weather KYM used for infrastructure construction such as WRD pad, ROM stockpile pad bases - AMDMP Table 2.2 p18. Management measure aimed to reduce generation and transport of oxidation products: • Paddock dumping of waste not end dumping. • PAF waste materials contained in KYM, MSM and SIM are stored in PAF Cell 1 in the F-East WRD to limit oxygen ingress and percolation of water. • Various water management infrastructure interception trenches, containment dam, bunds/berms, interception drains to reduce moisture contact with WRD. WRD design and construction: • A store and release cover is proposed to inhibit oxygen and moisture ingress into the facility and into PAF cell. • 2.5 metre thick base of NAF KYM. • 2.5 m thick cover of NAF KYM and NAF MSM rock armour / erosion control. • 4m thick side cover of NAF KYM. • The base of the WRD will extend beyond the sides of the planned WRD landform to include the catch drains and bunds. • Storage of PAF material in 100 000 m^3 cells that will be encapsulated in NAF KYM within the WRDs. • PAF cell covered with 1.2 m thick layer of NAF material followed by rock and eventually rock armour and soil that will be track rolled and shaped for drainage. • Interception of runoff drainage trenches, stormwater levees, ROM stockpile pad levees, temporary levee around F East pits and WRD.
6.1.5 Minimising self-heating and AMD potential	**Where** AMDMP **How** Self-heating has not been identified at Roper Bar.

	Both self-heating and AMD potential will be prevented or minimised through mine waste handling and storage as outlined in 6.1.4 of this Checklist. Source-Pathway-Receptor analysis has been completed outlined in GHD 2015.
6.1.6 Minimising AMD risk at sites dominated by PAF waste rock	**Where** AMDMP (Reference: GHD 2015) **How** Roper Bar is not dominated by PAF. The volumes of PAF are small as shown in GHD 2015 Table 5 on page 21, which indicates total % PAF in waste and ore is <1%.
Management of tailings to minimise AMD ***6.2.1 Overview***	**Where** AMDMP (Reference: GHD 2015) The ore processing methods described will not generate tailings. **How** The processing of the iron ore involves crushing and dense media separation only. No tailings are produced in this method.
6.2.2 Water covers for tailings	Not applicable. Tailings are not generated (Refer to Section 6.2.1)
6.2.3 Covers for tailings	Not applicable. Tailings are not generated (Refer to Section 6.2.1)
Soil cover systems for waste rock and tailings ***6.3.1 Covers on flat tops***	**Where:** Table 2.2 Appendix A **How** Soil cover system for the WRD is described in Section 6.1.4 NAF waste (specifically both weathered and fresh material MSM) is stockpiled for use as WRD capping material. This material will be compacted and profiled.
6.3.2 Treatment of outer slopes	**Where** AMDMP **How** Rock armour and soil, slopes compacted and profiled as noted above.
6.3.3 Cover design and performance	**Where** AMDMP Appendix A. **How** Store and release cover system. Encapsulation cell worked during C&M period.
6.4 Blending and co-disposal of wastes	No blending or co-disposal of waste occurs at Roper Bar Mine. Encapsulation of PAF waste within a lined containment cell in the NAF waste occurs.

7.1 Why and when do we need to treat?	No treatment as the AMD prevention and management measures have been successful to date.
7.2 General considerations for the selection of treatment systems	Not applicable at this time because no AMD has been generated.
Treatment technologies—active or passive? ***7.3.1 Overview***	Not applicable at this time because no AMD has been generated.
7.3.2 Active treatment systems	Not applicable at this time because no AMD has been generated
7.3.3 Passive treatment systems	Not applicable at this time because no AMD has been generated
9c). A strategy for the ongoing monitoring of PAF material, including threshold trigger levels and mitigation responses;	
9.1 Introduction	**Where** AMDMP (References: PES 2013, GHD 2015) The AMDMP did not have: • A conceptual site model. • Water qualities. An assessment of appropriate water quality cannot be judged using the AMDMP. Financial assurance and technical provisioning was not sighted in the AMDMP. To date the assessments and available monitoring data indicates a low risk of AMD post-rehabilitation. However, information on provisioning for ongoing geochemical test work was not provided. Geochemical sampling and analysis results since mining recommenced were not sighted in the AMDMP. Ongoing ABA and XRF analysis results were not sighted in the AMDMP **How** A systematic approach to monitoring mine waste and checking for PAF material is outlined in (PES 2013, GHD 2015). Sample characterisation during mining will be by XRF providing Total %S values with additional check analysis by NATA credited laboratory. Blast hole and ore grade control drilling programs will supply samples in advance of mining. Purpose of the monitoring and responsibilities for doing the work are defined.

	The AMDMP indicates additional static and kinetic testing is needed, which includes expansion of kinetic testing to 11 columns to test all three main geological units KYM, MSM, SIM, waste rock WST and also the five (5) main ore types DSO, BDSO, DMSO, SIDO, LGO Oxygen consumption tests are suggested in the AMDMP. ASLP testing to increase understanding of metal leaching potential from the geological units.
9.2 Performance evaluation	**Where** AMDMP Table 2.2 Section (Item Performance Criteria) on p 18 **How** Performance Criteria are listed in Table 2.2 p18: • Zero discharge water in contact with waste material. • Maintain ambient downstream water and groundwater qualities particularly pH. • Soil pH between pH 6.0 to 8.5. • Inventory of all sources of acidity defined by Total S of <0.3%. • Trigger levels – Total %S used. • Monitor grade control bores at 50 m lines test on site XRF for total S with PAF >0.3%total S. Trigger Levels are discussed in the AMDMP Table 2.2 (Item Contingency Planning P20). Trigger levels for field waste characterisation are based on Total %S measured in the waste material. On site XRF laboratory assays of waste material will determine the Total %S levels. A Total S level of 0.3% is used to separate NAF from PAF material. Two key values of 0.25% and 0.30 % are used to trigger follow up actions to confirm the nature of the material. Material with Total S values of between 0.25% and 0.3% will undergo further field testing by paste pH and or NAG pH measurement. Paste pH values of <4.6% and NAG pH levels of <4.5% trigger the requirement for laboratory analytical assessment of ABA. Total S values of >0.3% trigger the requirement for field paste pH and NAG measurement and ABA laboratory assessment. Performance of on-site laboratory XRF testing will be assessed based on the calibration of XRF results against NATA accredited laboratory analyses of 10% of all analysed samples.
9.3 Conceptual site model of AMD processes	**Where** Not provided in AMDMP. Reference (GHD 2015)
9.4 Monitoring	**Where** AMDMP Table 2.2 p19 and P20. **How** Water monitoring in: • Open pits, around WRDs, ROM pads, LGO stockpiles and other surface water control infrastructure. • Surface water. • Ground water. • Pit wall seepage. No results and no trends/changes in data over time supplied.

	The AMDMP references the Water Management Plan (WMP). The AMDMP states that the WMP contains water monitoring procedures and provides for assessment of analytes including pH, EC, acidity, alkalinity, sulfate and metals. Concentrations of these analytes will provide information on the presence of AMD.
9.4.1 Examples of parameters to monitor on site	**Where** AMDMP Table 2.2 p 20 **How** Reference is made to the site WMP for information.
9.5 Data storage, evaluation and reporting	No indication of the methods for data storage, evaluation and reporting are given in the AMDMP.
Appendix 1 Table A1 – Elements of an AMD monitoring program.	**Introduction** Roper Bar Mine does not have the following facilities that are listed in Appendix 1 of this Checklist: • "TSF, tailings dams". • "Underground mines". • "Heap and dump leach piles". Facilities as defined and listed in Appendix 1 that occur at Roper Bar are commented on below. **General** No data or information was sighted in the AMDMP for the components and parameters in this Appendix except for Production Geochemistry - geochemical classification. Some historical data and information can be found in References GHD 2015, PES 2013. **WRDS and ore stockpiles** No data or information was sighted in the AMDMP for the components and parameters in this Appendix except for Geochemical characterisation of lithologies for static and kinetic testing. **Pits/open cuts** No information or data on the components in this facility were seen in the AMDMP. **Other facilities** No information or data was sighted in the AMDMP on the components of this section.

5. Recommendations and closing comments

The following recommendations are made on the basis of this review and to ensure the AMDMP is consistent with the Checklist, the Handbook and Appendix 1 Table A.1 – Elements of an AMD monitoring program.

The AMDMP should clearly demonstrate sequential development and the changes over time between previous AMD Management Plans and investigations. To this end Section 1.4 entitled “Status Quo” could include the status quo, in summary, of AMD test work and results, and of the water quantity and quality monitoring. The water quality results can be used to indicate effectiveness of the AMD management measures implemented and can be used to complete Appendix 1 of the Checklist.

Throughout this review where summarised data and information are recommended it is suggested that Tables be used, if appropriate and practical.

The AMDMP should provide substantive evidence, in a highly summarised format, that it meets the Handbook guidelines and Checklist requirements. Summarised data and information about;

- The AMD testing methods used
- The numbers of samples taken, tested and analysed, per test method, and a summary of the analytical results
- A record of changes and differences, in this data and information, between consecutive management plans and investigations
- The Total S results and material characterisation
- Planned geochemical testing to fill data gaps.

Whether the on-site XRF has been purchased and is used is unclear. If an on-site XRF is being used the number of samples analysed and results produced should be quoted. The numbers and results of samples checked by an outside laboratory to determine the precision of the on-site XRF should be stated.

The structure of AMDMP Table 2.2 should be formatted to;

- Include all Checklist topics.
- Follow the Checklist sequential layout of topics and items.
- Provide data and information for Appendix 1 of the Checklist.

Re-structuring the Table in this way will;

- Assist communication with the regulator
- Expedite the review of future AMD management plans by the DoE
- Simplify the updating of the AMDMP
- Reduce the independent reviewer AMDMP review time.

The AMDMP identifies the need for additional geochemical test work, but only suggests rather than commits to the tests that will be done. The test work can be prioritised, scheduled and planned to fit in with the mining timeline, and this information included in the AMDMP. Firm commitment on the test work methods to be used can be given and can be based on the previous test work results.

A summary of previous and most up to date test work results provide evidence for the choice of test work method. This summary can be included in the AMDMP.

Additional static test work is suggested in the AMDMP (assessment of sulfate-sulfur and chromium reducible sulfur), but a clear commitment to this work with a sampling and testing schedule is needed.

The AMDMP states that the existing columns predominantly test KYM material. It also suggests that five (5) additional columns are needed to expand testing to include all ore types and the new geological classification of waste materials into KYM, SIM and MSM and waste (WST). The number of columns suggested and the number of different materials to be tested differ. Explanation of this difference is required.

The construction of planned leach columns (material per column) should be included in the AMDMP.

The usefulness of the previous 6 columns needs to be stated and this statement based on up to date test results. If test work has not been continued then the reasons for this need to be given.

Confirmation of the chosen kinetic testing methods is required. The uncertainty on the way forward on test methods, amplified by the statement "if undertaken" (in regard to doing column leach tests) needs to be removed by commitment to specific tests to be made in the AMDMP.

The AMDMP should contain summarised quantity and quality monitoring results for surface water, groundwater and any other mine affected water such as, in-pit, in collection trenches, seepages, in-pit and from the WRD and stockpiles or stockpile pads. Key analytes in water monitoring, which reflect AMD status e.g. pH, EC, SO_4, specific indicator metals, should be noted. Comment on salinity should be given as this aspect is part of the AMD continuum.

Trends in the water monitoring data, such as deterioration in water quality and decrease or increase in flows, should be identified. Changes that can be ascribed to the effectiveness of AMD management measures should be noted.

Other information needed to ensure consistency with the Checklist includes:

- Information about data storage, evaluation and reporting.
- A copy of the AMD conceptual model.
- Diagrams of the Source-Pathway-Receptor analysis can be provided in the AMDMP together with a copy of the Block Model.
- A diagram of the construction method of the WRD. This is would be in addition to the PAF cell construction diagrams that were proved in Appendix A of the AMDMP.
- Information on financial assurance and technical provisioning (required in Section 9 of the Handbook)

A financial provision for ongoing AMD monitoring, water monitoring and geochemical test work would align the AMDMP with the Checklist.

Comment should be given on whether the site works that were used to remove redundant infrastructure and material stockpiles impacted the level of AMD risk and the way this risk is managed.

Review and edit the content in Table 2.2 to ensure it is clear and concise. Avoid cutting and pasting text from previous reports where doing so causes a reduction in the clarity of information in the Table.

Expand the Abbreviations List to include all technical and other acronym definitions to prevent confusion and to assist the understanding and reading of the AMDMP.

Regular review of the AMDMP will enhance continuous improvement in AMD management.

6. References

Where gaps in data and information were found, these were investigated by reference to existing reports to determine if adequate assessment had been made during the AMD campaign for the Roper Bar Mine. Documents referred to and found to contain pertinent information included:

- EcOz 2012 Acid Metalliferous / Mine Drainage (AMD) and Management. Western Desert Resources Roper Bar Project. Report DW120007-C0302. Report prepared by EcOz Environmental Services, June 2012.
- PES 2013 AMD risk assessment and management Western Desert Report Reference No: PES11009. Report prepared by Pendragon Environmental Solutions, April 2013.
- GHD 2015 Acid and metalliferous Drainage Management Plan, Care and Maintenance - Mining Management Plan, Roper Bar Iron Ore Project, Western Desert Resources Limited, GHD 2015.

DASalmon

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Appendix C: Standard Operation Procedure: Field Tests.

Waste Rock Sampling Procedure

For Management of Acid Metalliferous Drainage

Roper Bar Iron Ore Mine

NATHAN RIVER PROJECT

Date: August 2019

Report No.: NRR19 - 02

Author: Gavin Otto, Geology Manager

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TABLE OF FIGURES

PURPOSE

This procedure outlines the methods required to collect and analyse geochemical samples of waste material mined at Roper Bar for the purpose of identifying any potentially acid forming (PAF) material for selective handling and placement.

SCOPE

This procedure is applicable to waste rock sampling of blast drill holes, mine faces, pit floor sampling and wall sampling.

This procedure forms a part of the Nathan River Project Acid Metalliferous Drainage Management Plan

RESPONSIBILITY

The Geology Department is responsible for the identification and communication of PAF locations.
The Mining Department is responsible for the transport and storage of PAF. The Environmental Department is responsible for the monitoring of surface and ground water to identify whether any acid mine drainage is occurring.

The Manager/Supervisor shall ensure that:

- Waste rock is adequately characterised through sampling and analysis
- Any identified PAF is communicated in a timely fashion to the Mining Department
- Adequate resources are available to conduct waste sampling
- Adequate training is given to all staff using this procedure

The OHS Officer:

- Will ensure that all related sampling procedures are being adhered to by all workers;
- Will ensure that all workers involved in sampling procedures have been adequately trained in conducting hazard analyses and managing risk associated with waste rock sampling ;
- Will respond immediately to all identified substandard conditions, hazards, defects, or noncompliance to the sampling procedures.

The Worker:

- Will participate in any team identified as needed to develop procedures for protection as required;
- Will inspect and asses the blast pattern environment and deem it safe to work in;
- Is required to record the findings of all potential hazards;
- Is required to record the findings of all equipment inspections;
- Will report immediately to the supervisor any identified defects, hazards, substandard conditions to his/her supervisor;
- Will abide by all waste rock sampling procedures

DEFINITIONS

Detailed geochemical assessments have correlated exploration data captured from waste rock laboratory assays, portable XRF data and laboratory based acid base accounting (ABA) tests (refer to AMDMP for full details). These assessments have determined that a simple and conservative definition of PAF at Roper Bar geochemically is:

NAF < Total Sulfur 0.3% < PAF

PROCEDURE FOR WASTE ROCK SAMPLING

- The working files for the waste rock sampling are within **S:\MINING\Waste Rock Sampling.**
- On a daily basis check with engineers and drilling contractor on the status of drilling on blast patterns and any upcoming loading of explosives.
- Consult with the drill and blast engineers to obtain both digital and hard copies of the maps and hole collar information for sampling planning purposes.
- Plan the sampling of the pattern with the drilling schedule to ensure there are sufficient holes to be sampled and that there is no interference with loaded holes. (Figure 1).
- A regular sampling pattern should be used that does not discriminate by stratigraphy. It is recommended to sample every second hole on every third line of holes on a staggered grid pattern of approximately 10 x 8 m.
- **Use positive communication with the drillers/shot firers when entering and leaving the pattern.**
- **Under no circumstances is it safe to enter a drill pattern if blast holes havw been loaded. Loaded shots will be cordoned off with YELLOW cones.**
- Ensure that completion of sampling can be undertaken prior to explosive loading of the holes. Sampling of spoils after loading of explosive may contaminate the sample and poses a risk to the onsite laboratory.
- Areas of low grade ore on the margins of the waste are to be included in the waste sampling pattern. Sample up to the ore boundary; the map will have the ore zones delineated.
- When sampling the blast hole spoils, minimize the amount of spoil from re-entering the drilled hole. With the bottom of the trenching shovel facing away from you strike the point vertically into the cone as close to the hole collar as possible. Draw the shovel back toward you spreading a cross sectioned of sample away from the centre of the cone. Carefully collect a trenching shovel blade of drill spoil and place in a sequentially numbered calico bag and secure. (Figure 2). The assay sample weight should be 2 – 3 kg.
- Ensure the sample is recorded on the Waste Rock Sample Sheet recording the Blast Hole ID, Sample ID, Sample Type, Easting and Northing. All fields and header details of the Sheet are to be completed with the relevant information (Figure 3). The “Unit” field must be filled out for all samples, as this is used in characterising the waste. Generally, the shot will be either all “KYM“ (Kyalla Member- on the southern side of the ore at F-East and at the western side of the ore at E-East) or “MSM” (Moroak Sandstone- on the northern side of the ore at F-East and the eastern side of the ore at E-East).

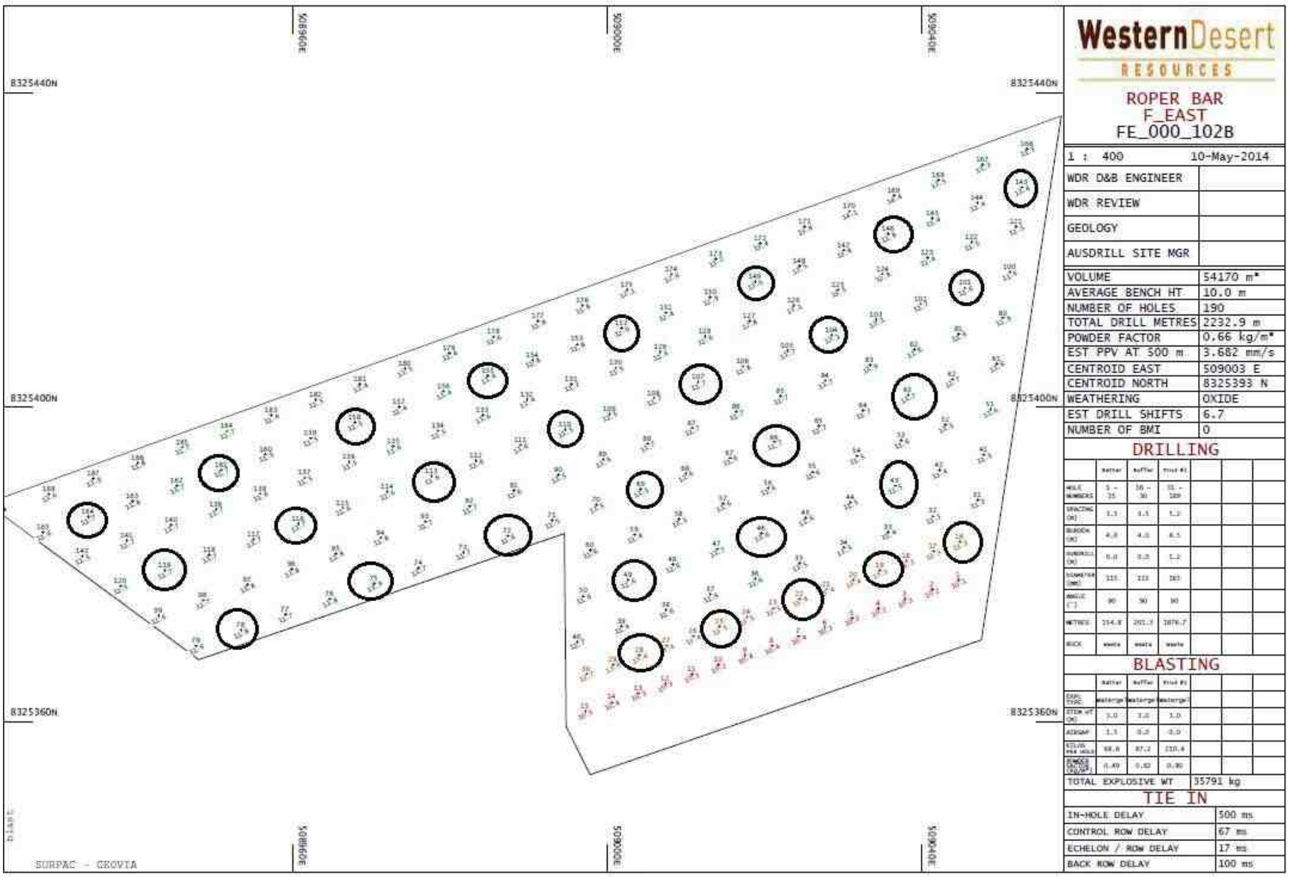


Figure 1: Blast pattern map showing coverage of collected waste samples from drill spoils.

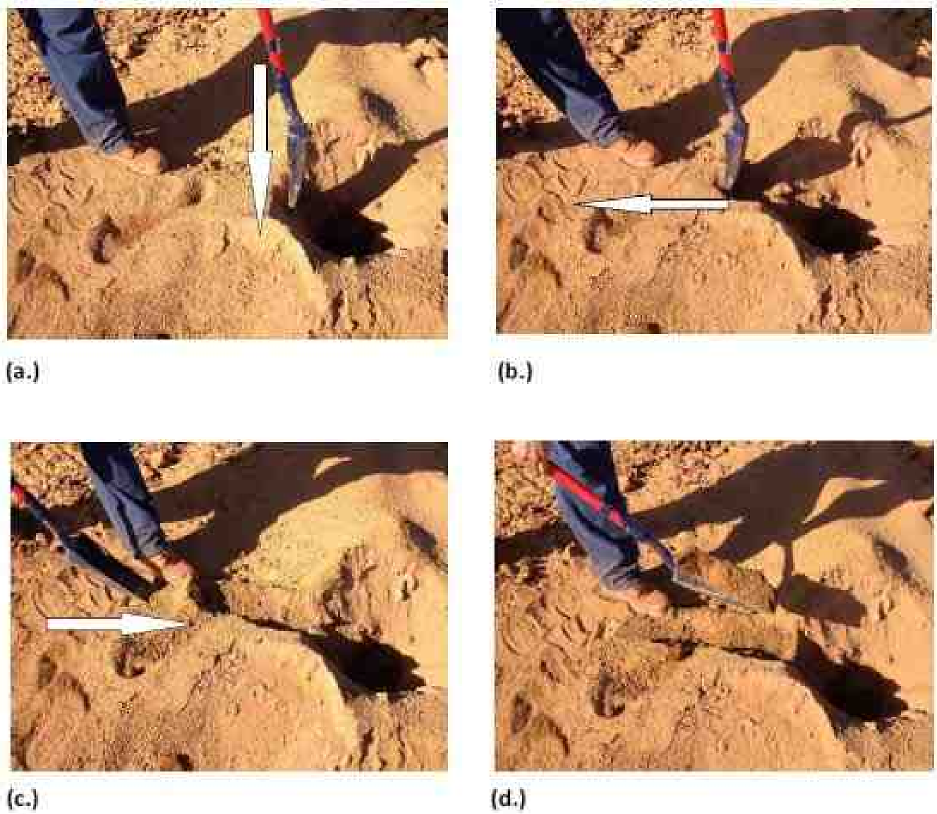


Figure 2: Blast hole spoils collection procedure.

Shot No: FE_000_107A		**Medium:** Blast Hole
Area/Pit: F-EAST		**Geologist/Sampler:** MB
RL (crest): 10	**RL (toe):** 0	**Date:** 2/05/14

BHID	Sample ID	Sample Type	UTME (x)	UTMN (y)	Unit	Lith1	Ox	SID	PY	Comments
37	FEWR 0195	Assay	508 430	8325 336	MSM	SST/SLT	W	5	5	

Figure 3: Waste Rock Sample Log Sheet

- Once the requisite data has been entered for the Sample Sheet, and the data entered onto the server, samples are to be submitted to the on-site laboratory for analysis.
- Approximately 10-15 samples per month are required for full environmental and geochemical test work at an offsite laboratory. These samples are to be randomly selected by setting aside all samples whose ID number end in “00, 25, 50, 75”. Ensure the on-site lab sets aside ~1kg of these designated pulps to store in a dry secure location for monthly submission.
- Full geological information from these waste samples (including lithology and mineral abundance) needs to be recorded for ongoing waste characterisation studies.
- At the end of each calendar month the designated waste rock sample residues secured by the on-site laboratory are to be sent to the off-site laboratory for acid-base accounting (ABA) testing and full geochemical analysis.

DATA PROCESSING AND INTERPRETATION

- Waste rock assays must be checked by the mine geologists when the results are returned by the laboratory. If PAF (>0.3 % S) is present then this procedure must be completed as soon as possible to develop a separate PAF mark out prior to any mining of the shot.
- PAF mark outs need to be developed for where there are two or more adjacent PAF samples. These need to be separate from ore mark outs and developed prior to any mining in the shot. The hanging wall waste, which may include PAF, is always mined first and prior to the mining of ore.
- Interpretation of the data is undertaken by the mine geologist. All waste rock sample results are imported into mining software to identify areas of PAF material. Polygons are designed around areas where two or more adjacent waste samples contain > 0.3 % S. These PAF polygons are saved and communicated to the Mining/Engineering Department for survey to mark up on the pit floor and be incorporated into the mining plan.

ENVIRONMENTAL IMPLICATIONS

- No environmental implications.

HEALTH AND SAFETY IMPLICATIONS

- This procedure is not to be completed on nightshift due to insufficient lighting. Dayshift only.
- Working on blast pattern, be careful and follow driller/shot firers’ instructions.
- No smoking, naked flames or metal implements permitted on loaded shot.
- Correct PPE to be worn where applicable. Hard Hat, ear plugs, safety glasses gloves etc.

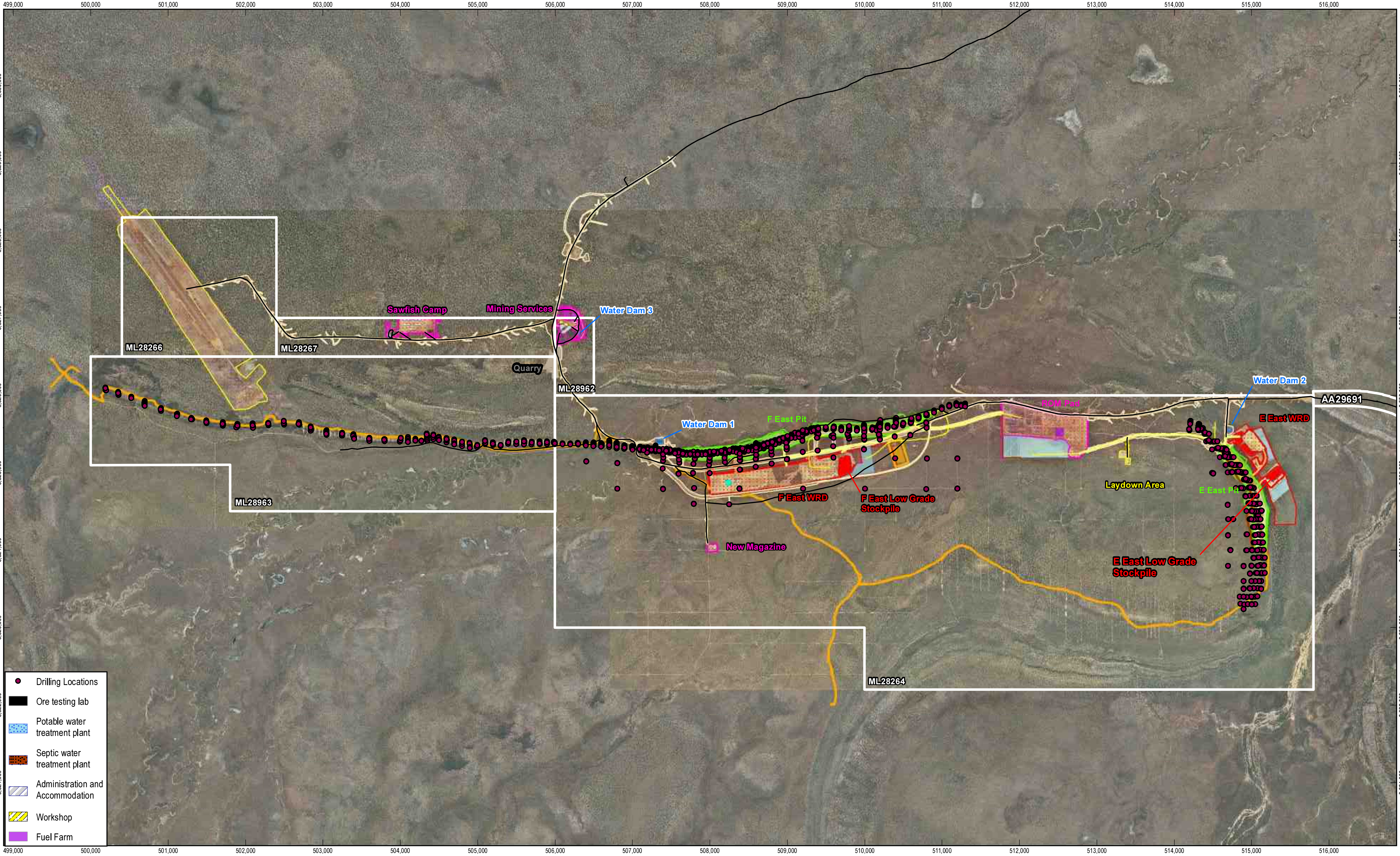
HAZARD & POTENTIAL INCIDENT CHECKLIST

- Take Five and assess potential risks prior to commencing task

LEGAL REQUIREMENTS

- None

Appendix D: F East and F West Block Models.



Paper Size A3

0 1 2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Levee
- Exploration Road
- Access road
- Dam
- Airfield additional disturbance
- LGO Field Stockpile
- Pits - constructed
- Pits - additional disturbance
- Waste Rock Dump - constructed
- Waste Rock Dump - additional disturbance
- Mine administration
- Mine administration - additional disturbance
- Extractive area
- Potentially Acid Forming Encapsulation Cell
- DMS Pad
- WDR Lease

GHD

WESTERN DESERT RESOURCES

WDR Pty Ltd (Receivers and Managers Appointed)
Roper Bar Iron Ore Project

Job Number	43-22061
Revision	A
Date	29 Nov 2014

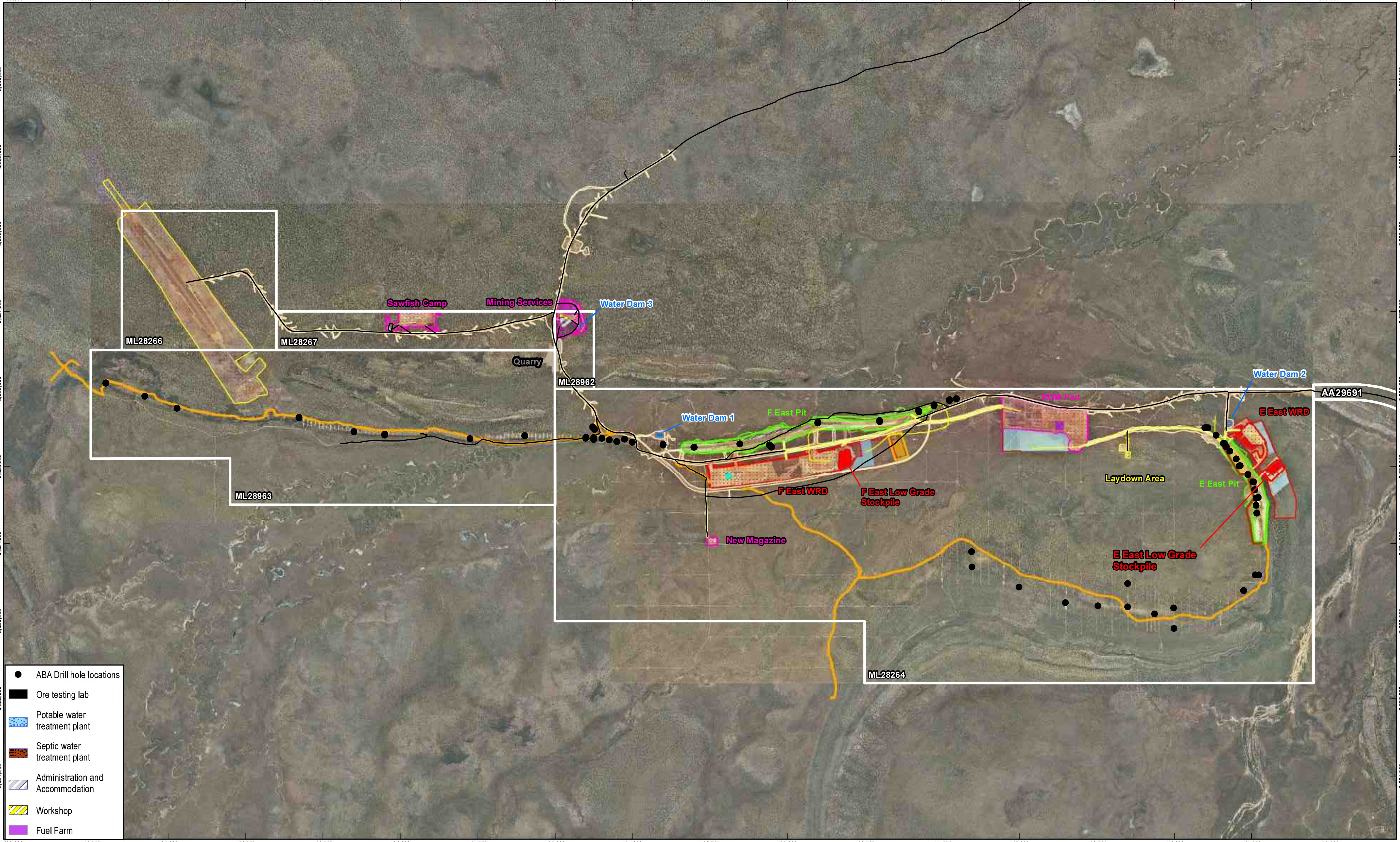
Appendix A

Lab Assay XRF Drilling Locations — Figure 6

G:\43\22061\GIS\Maps\MXD\43_22270_059_rev_a1.mxd

145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: GHD: Digitised Infrastructure, Drilling Locations (2014); Western Desert Mining: Infrastructure Layout, Imagery (2014)



Paper Size A3

0 1 2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Levee
- Exploration Road
- Access road
- Dam
- Airfield additional disturbance
- LGO Field Stockpile
- Pits - constructed
- Pits - additional disturbance
- Waste Rock Dump - constructed
- Waste Rock Dump - additional disturbance
- Mine administration
- Mine administration - additional disturbance
- Extractive area
- Potentially Acid Forming Encapsulation Cell
- DMS Pad
- WDR Lease

GHD | WESTERN DESERT RESOURCES

WDR Pty Ltd (Receivers and Managers Appointed)
Roper Bar Iron Ore Project

Job Number 43-22061
Revision A
Date 29 Nov 2014

ABA Drill Hole Locations

Appendix A
Figure 7

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145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: GHD: Digitised Infrastructure, Drilling Locations (2014); Western Desert Mining: Infrastructure Layout, Imagery (2014)

Appendix C – Geochemical Model Output

F West Pits 1 – 4 – Final

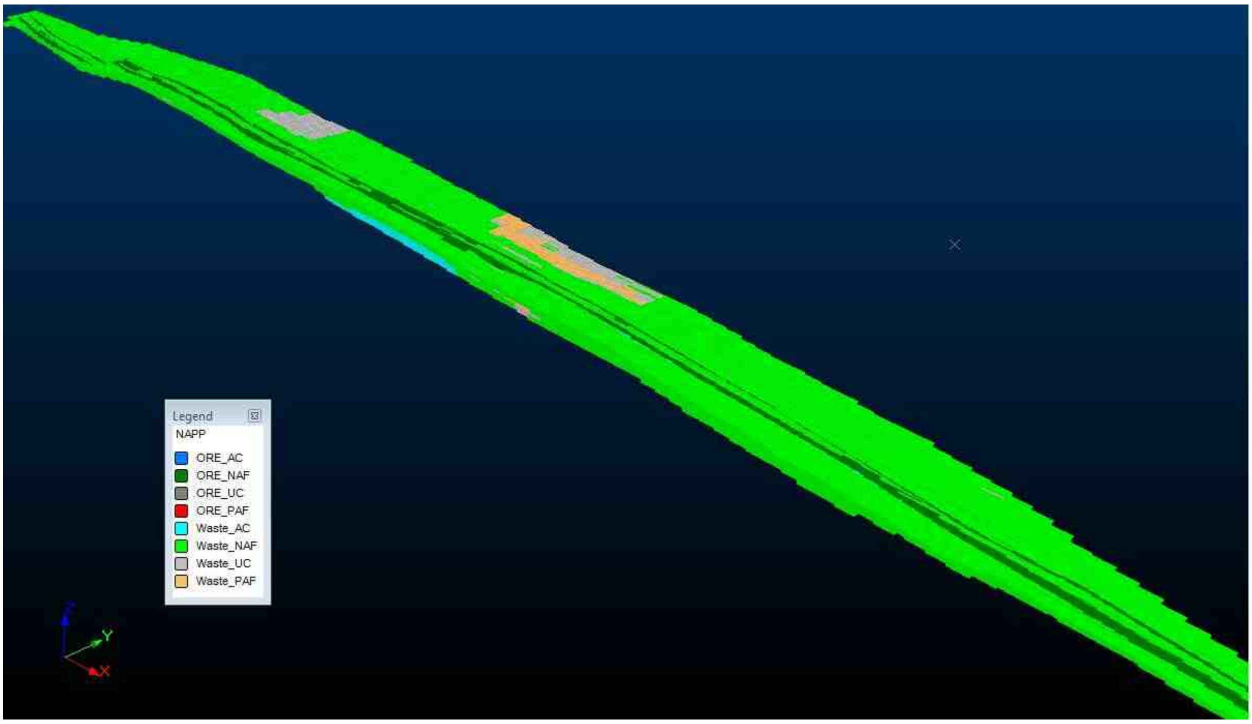


Figure 1 F West 1 Pit looking NW – classified using NAPP values. Perspective view.

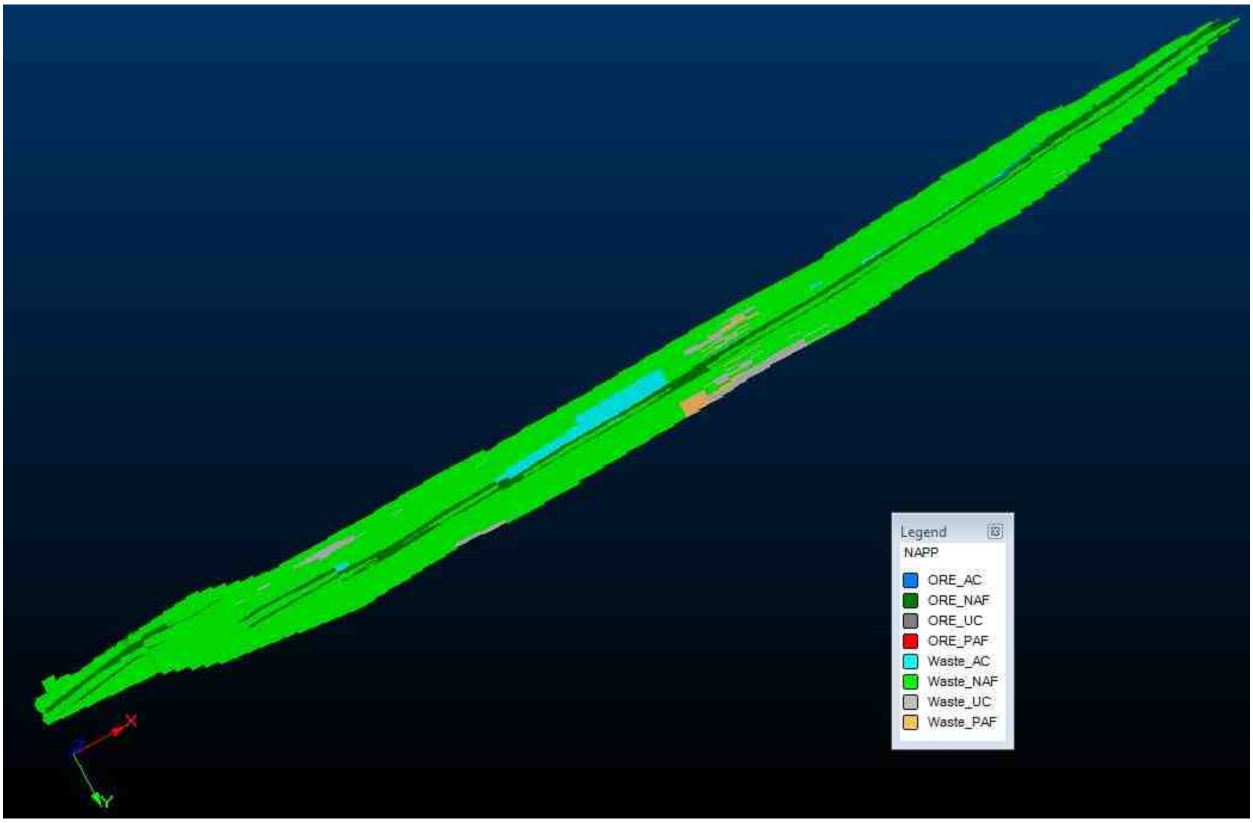


Figure 2 F West 1 Pit looking SE – classified using NAPP values. View from beneath.

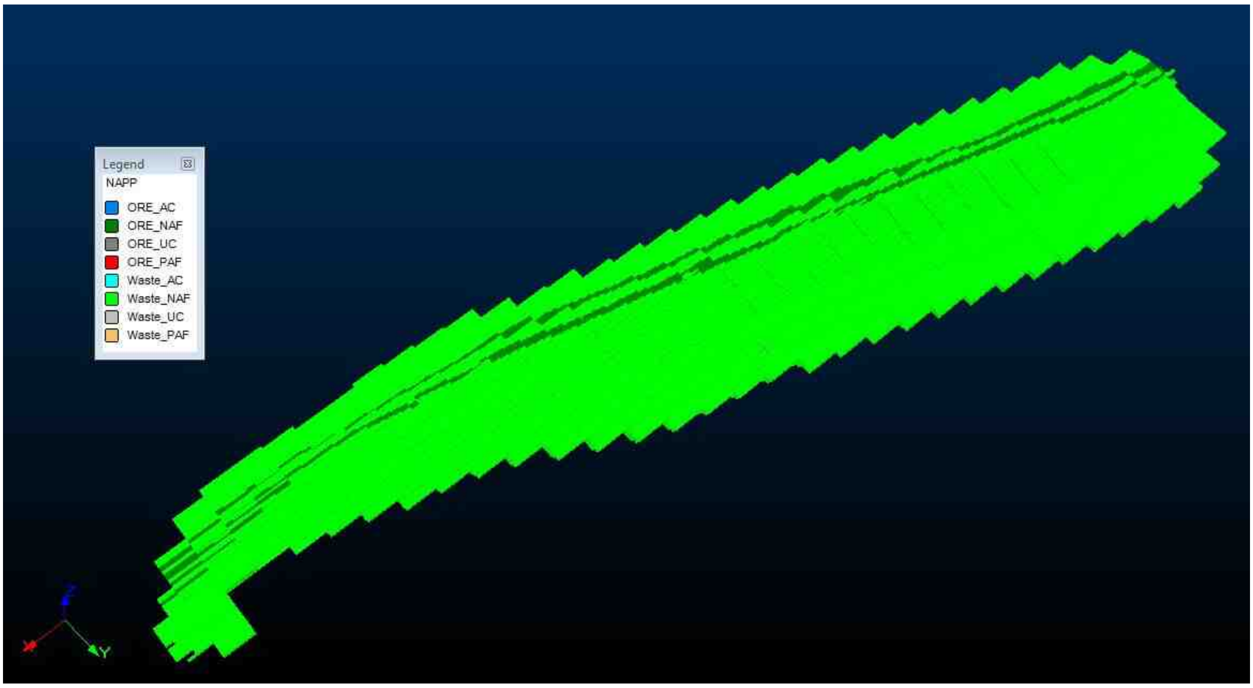


Figure 3 F West 2 Pit looking NW – classified using NAPP values. Perspective view.

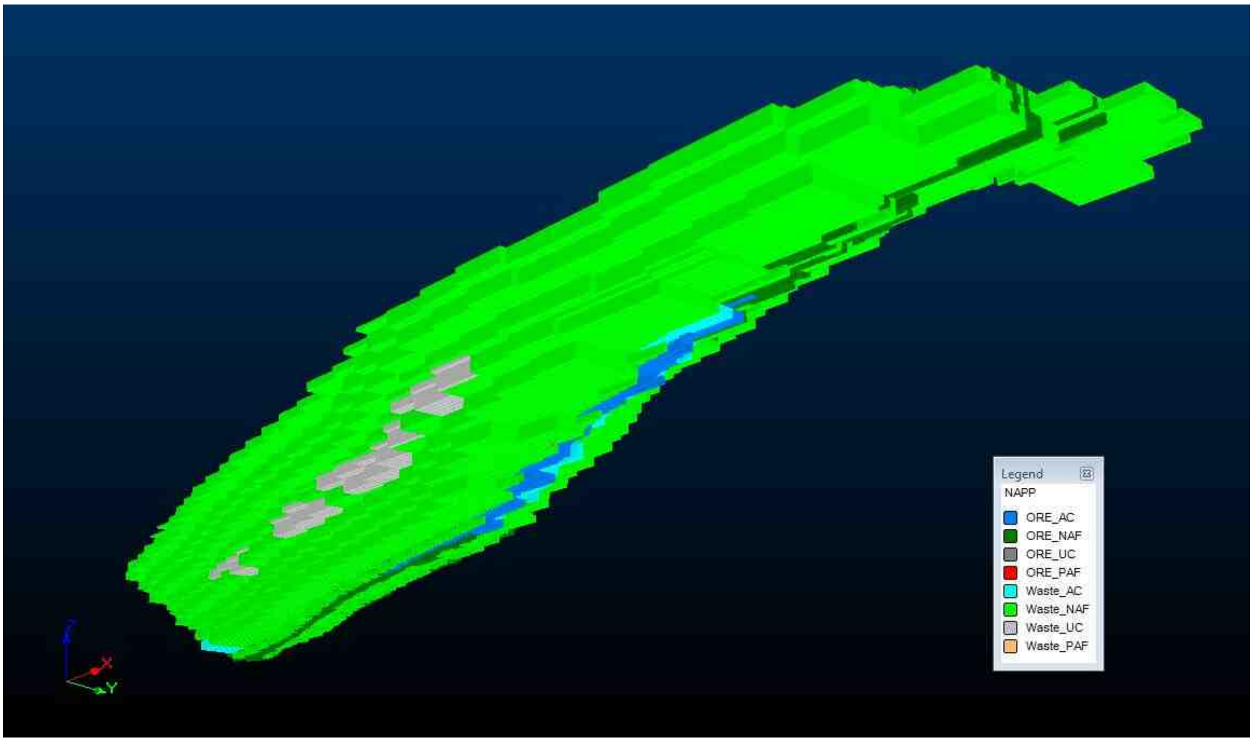


Figure 4 F West 2 Pit looking NW – classified using NAPP values. View from beneath.

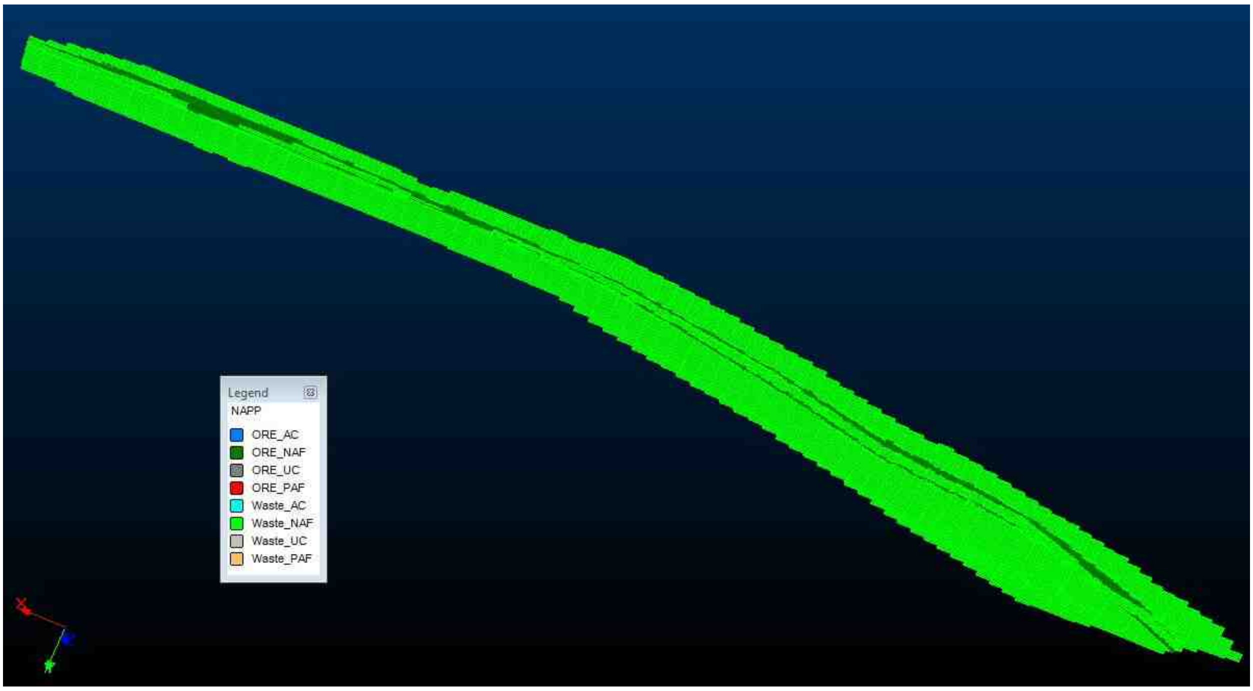


Figure 5 F West 3 Pit looking NW – classified using NAPP values. Perspective view.

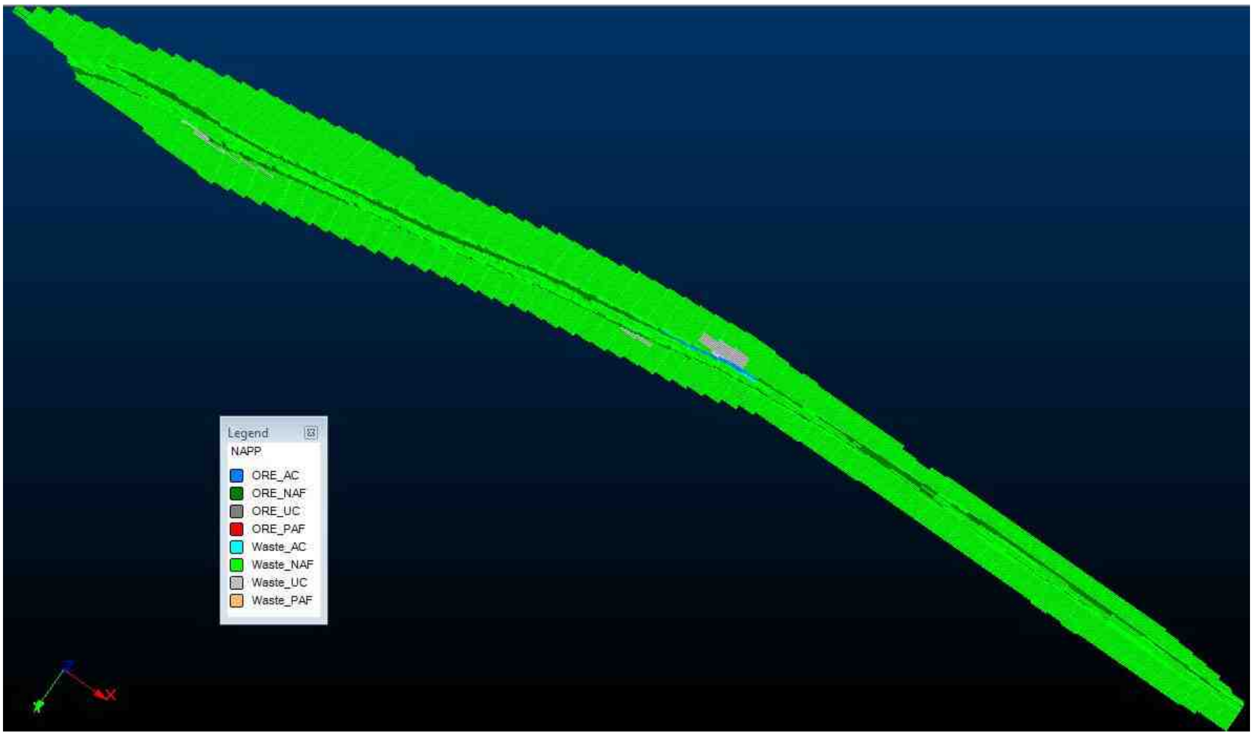


Figure 6 F West 3 Pit looking NW – classified using NAPP values. View from beneath.

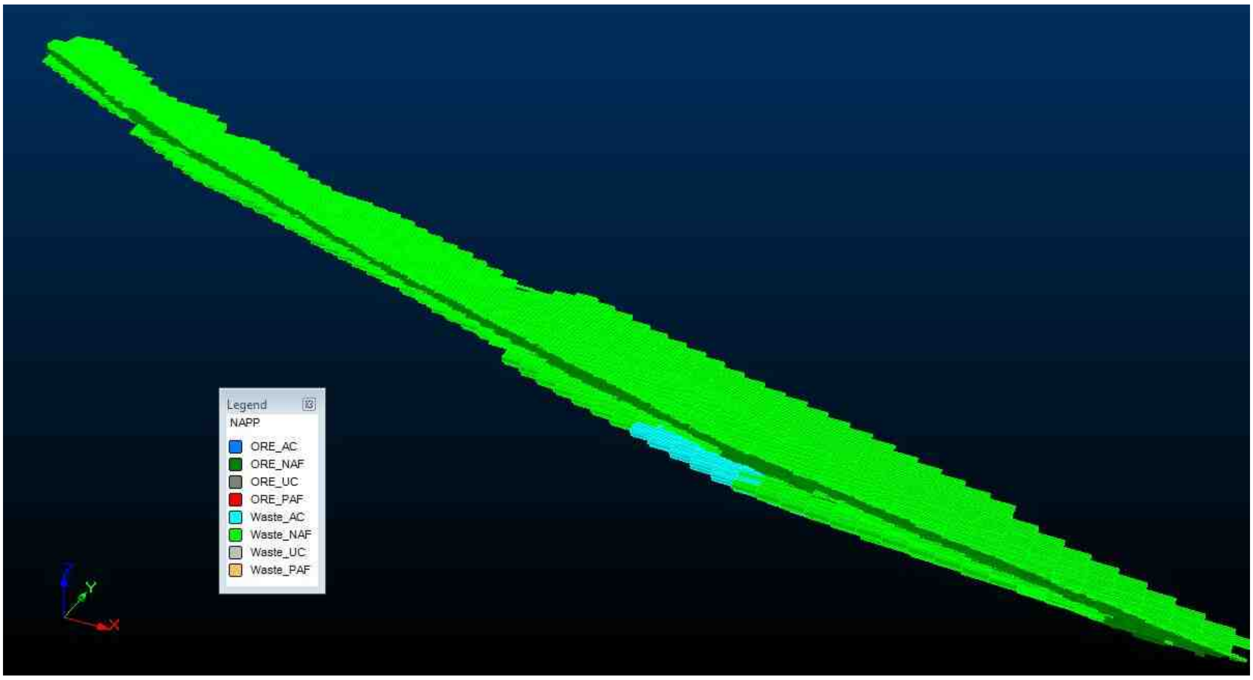


Figure 7 F West 4 Pit looking NNW – classified using NAPP values. Perspective view.

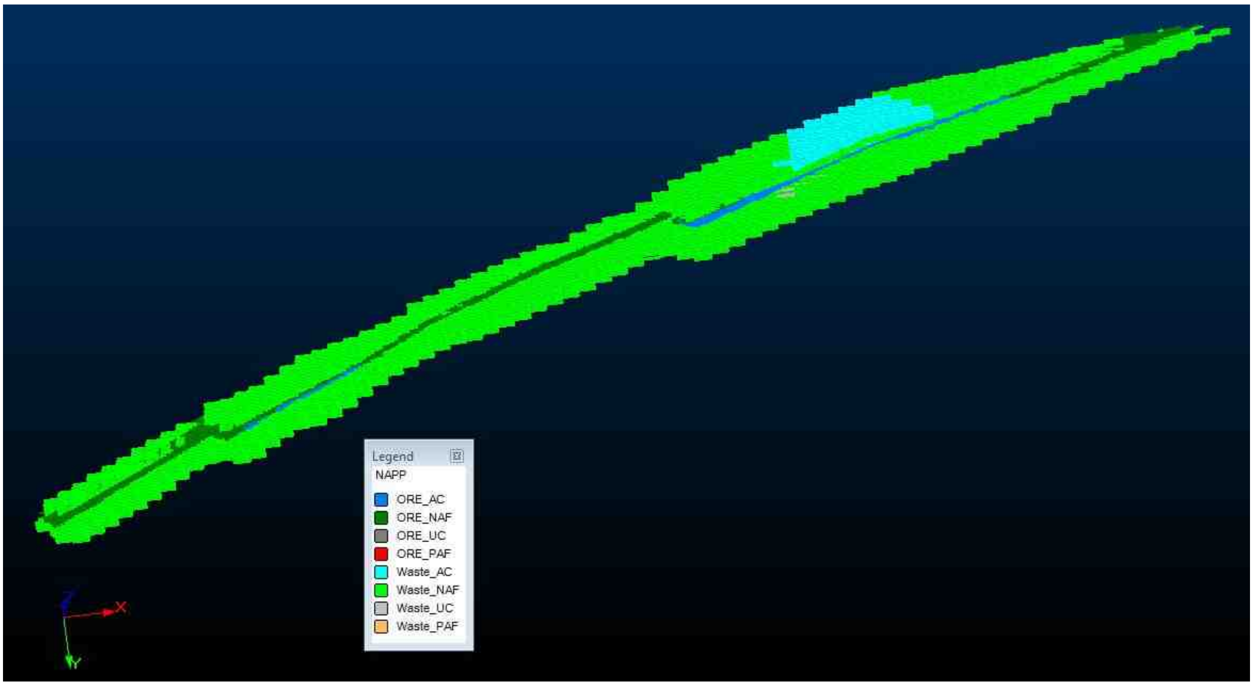


Figure 8 F West 4 Pit looking SE – classified using NAPP values. View from below.

F East Pit – Year 1

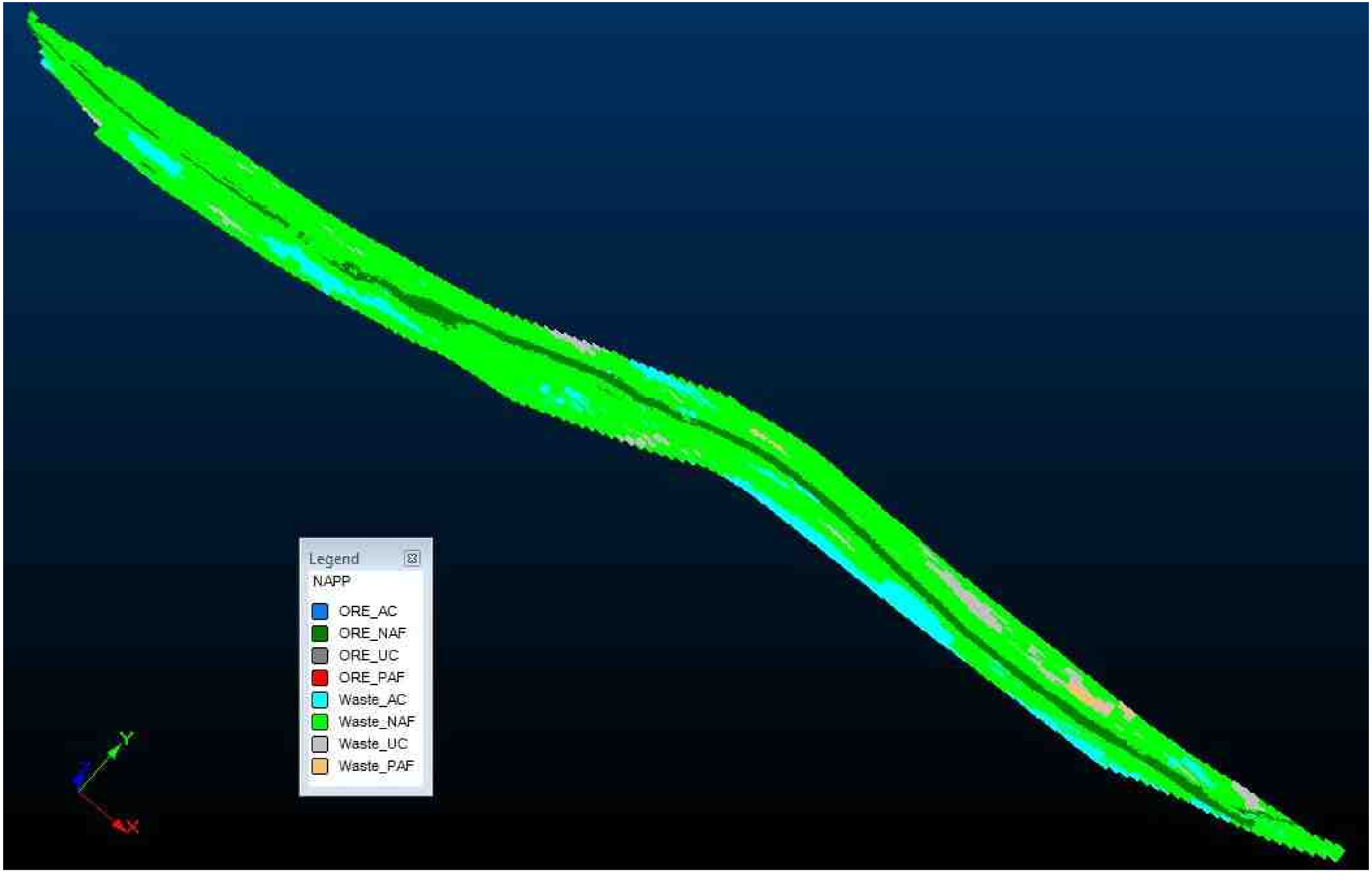


Figure 7 F East Year 1 Pit looking NW – classified using NAPP values. Perspective view.

F East Pit – Final

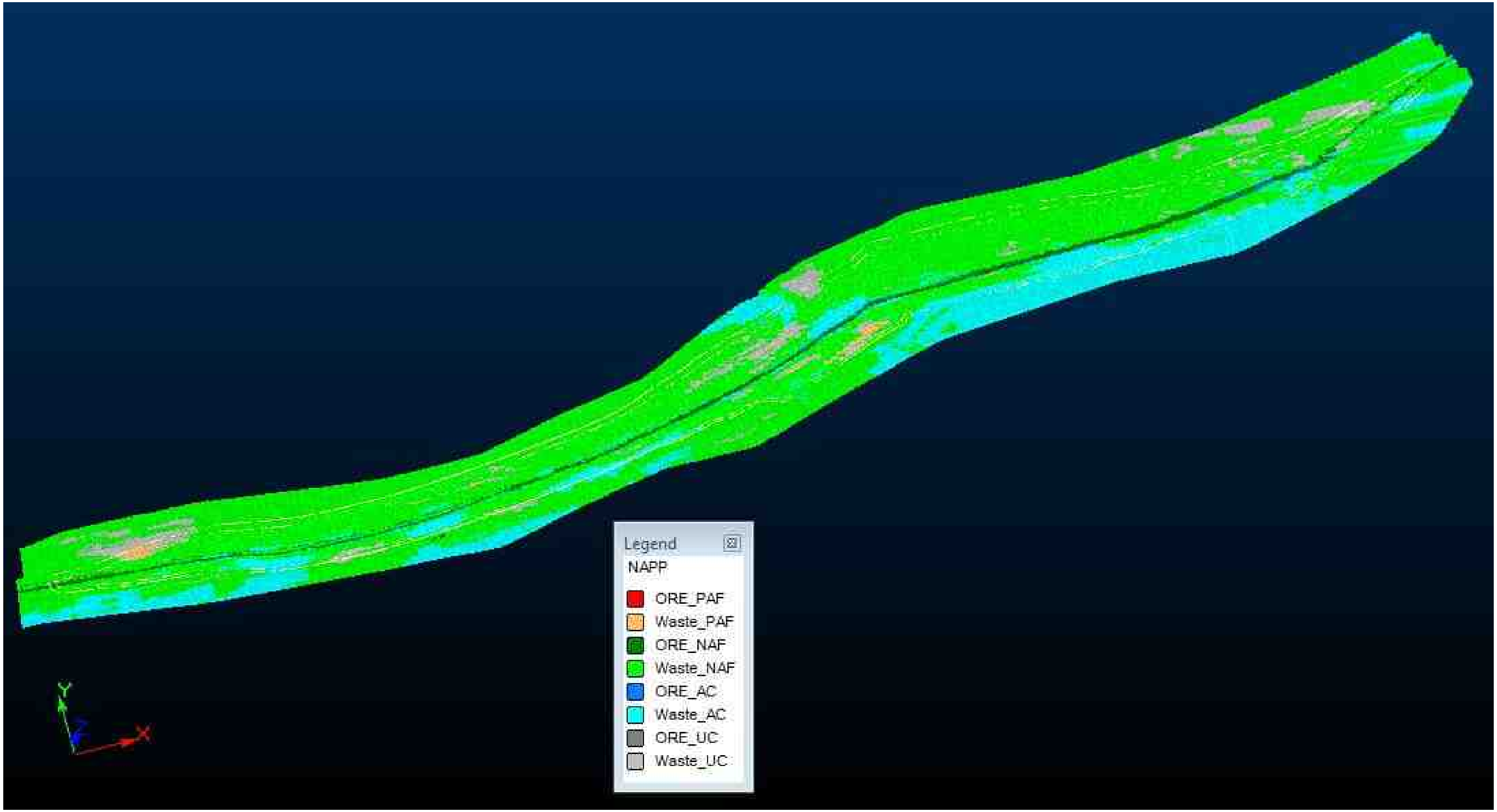


Figure 8 F East Final Pit Wall looking NE – classified using NAPP values. Perspective view.

E East Pit – Year 1

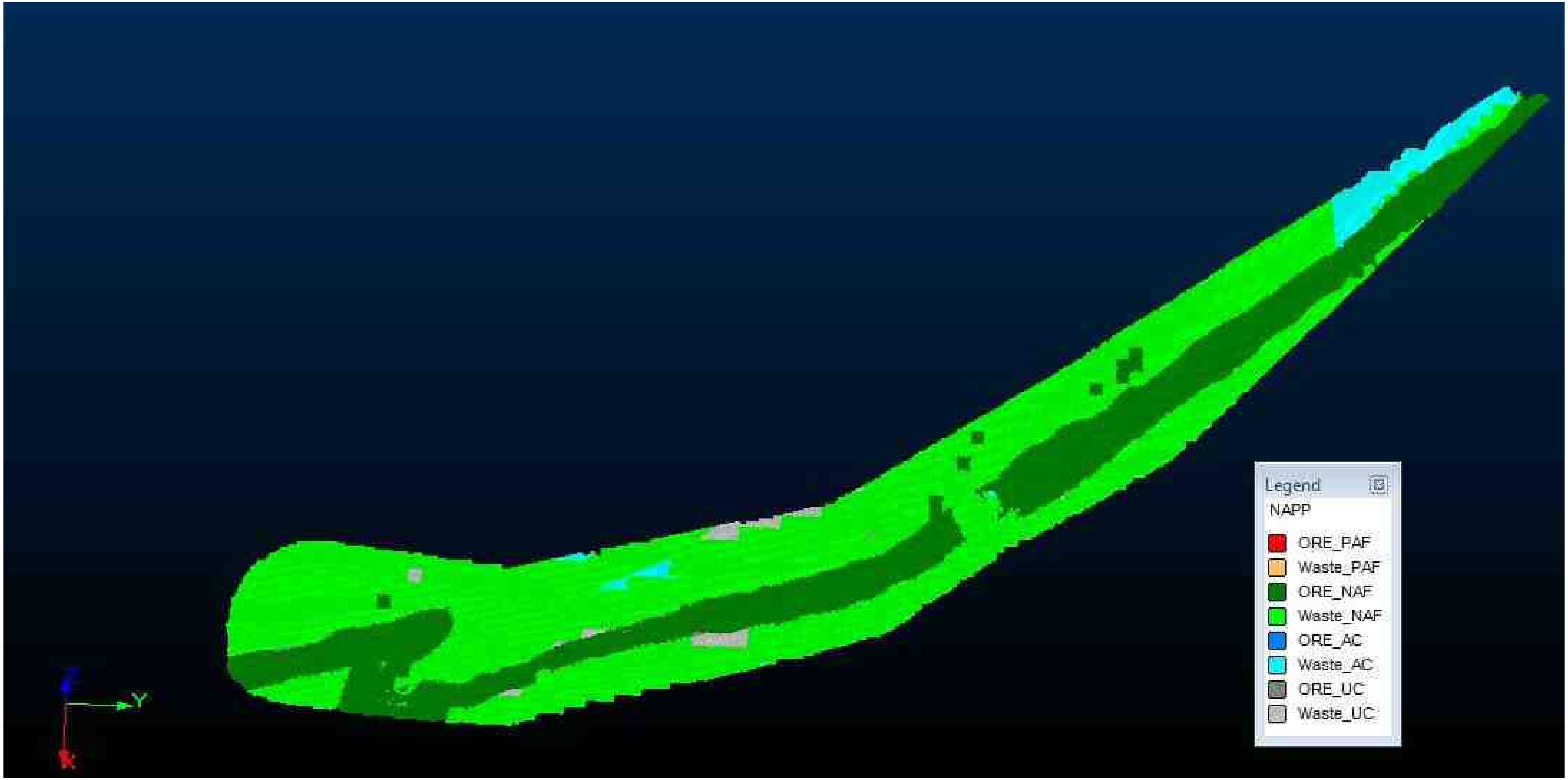


Figure 9 E East Pit Material Mined Year 1 looking from above – classified using NAPP values. Perspective view.

E East Pit – Year 1

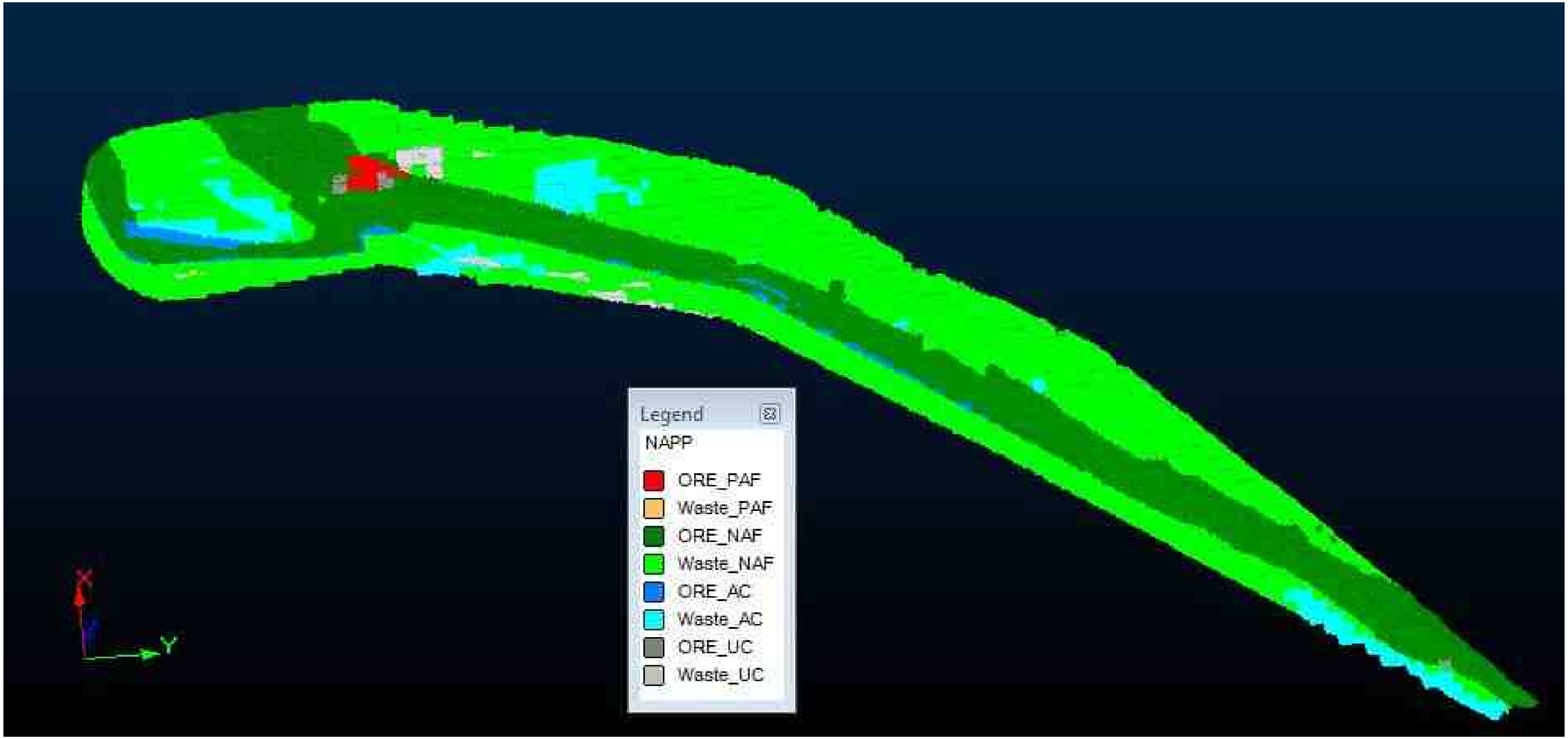


Figure 10 E East Pit Material Mined Year 1 looking from below – classified using NAPP values. Perspective view.

E East Pit – Final

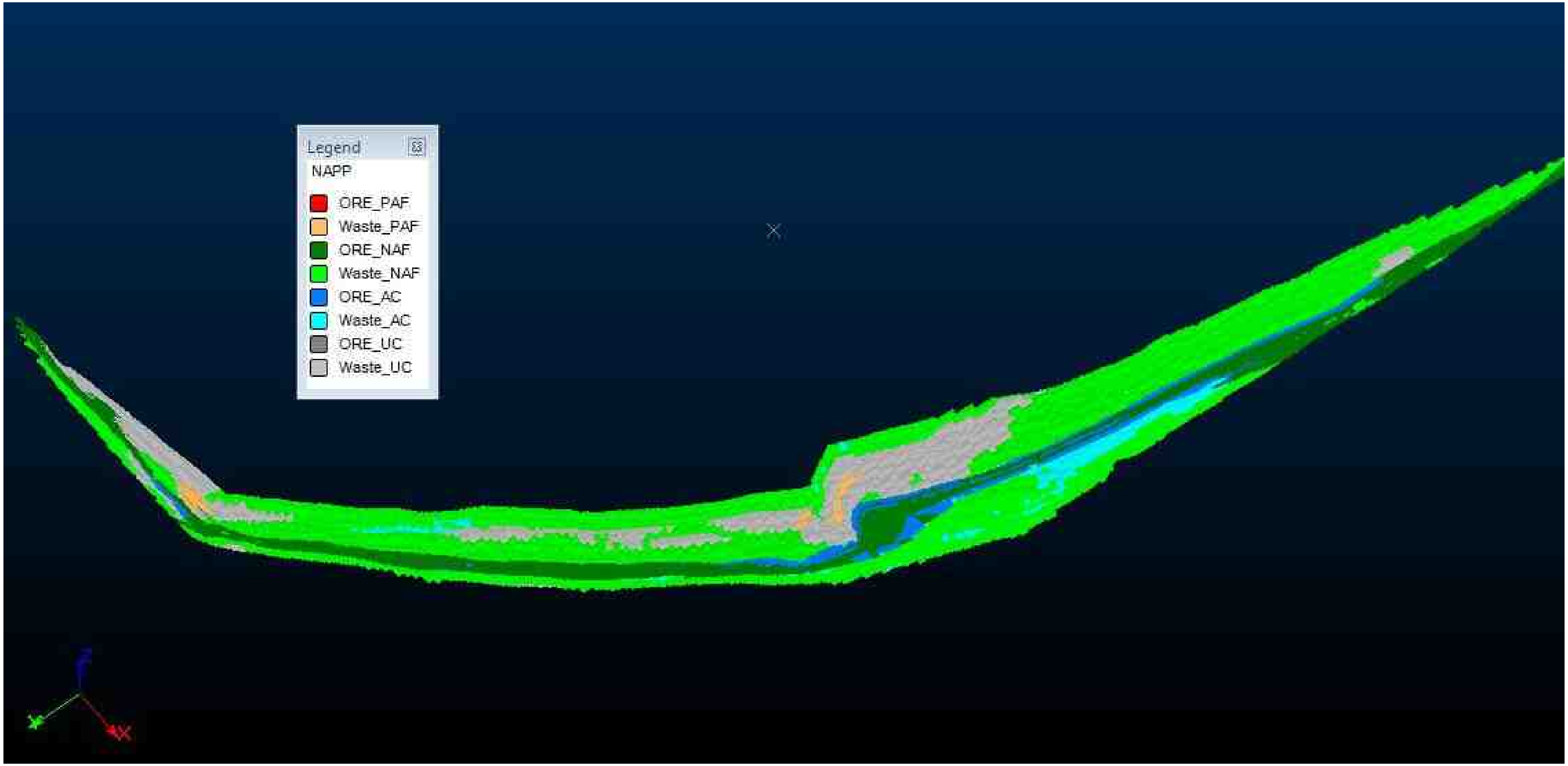


Figure 11 E East Final pit shell from beneath – classified using NAPP values. Perspective view looking NE

Appendix D – Geostatistics

GeoStatistics

Geochemical Model Validation

Grade block models were provided to GHD by WDR for the E East Pit and for the combined F-Pit Area (F East, F West 1 to 4). The block model contained estimates for total sulfur (%) and for CaO and MgO (%), as well as other elements used in metals assessments. The model grades were compared spatially against the laboratory assay XRF data and the Niton (handheld) XRF data, composited to 3 m lengths for total sulfur (%) only.

Generally; the laboratory assay XRF (LXRF) data is concentrated around the ore zones (SIM unit) and the Niton XRF (HXRF) data is from the waste zones (KYM and MSM units).

There is good spatial correlation between the two datasets and the respective block models, representative sections and plans are shown in the following sections (Figure 1 to Figure 13 inclusive).

E East pit Block Model Comparison – Total S (%)

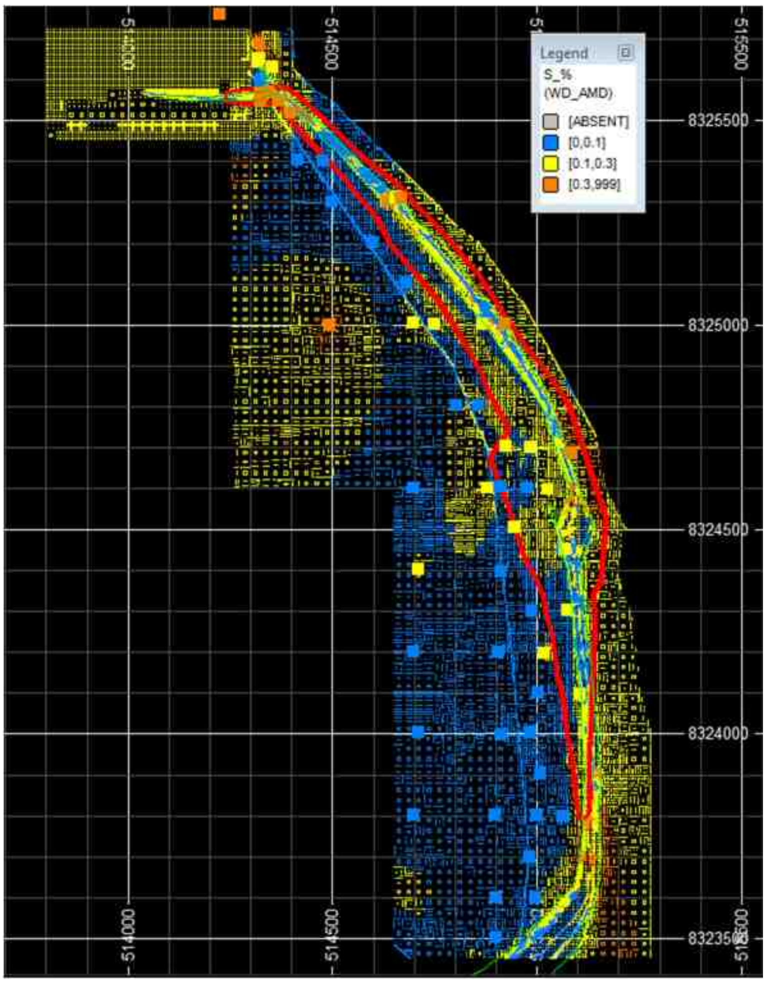


Figure 1 Plan View (0 mRL) – Block Model and HXRF data (large solid squares) coloured by Total S (%) – E East Final Pit Outline (Red)

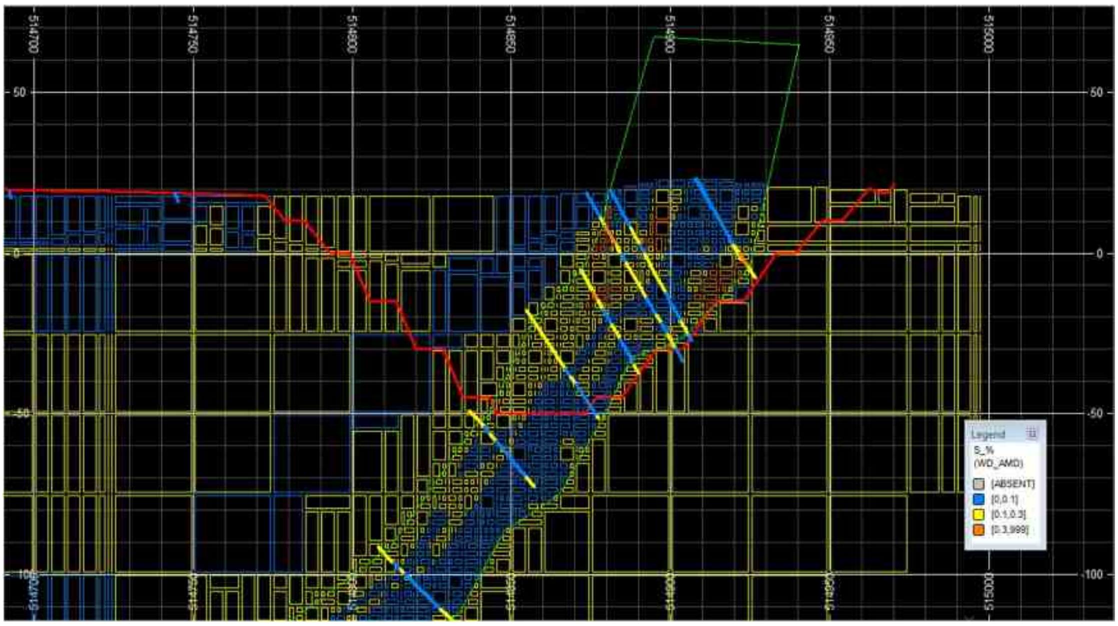


Figure 2 W-E Cross Section (8,325,000 mN) – Block Model and LXRF data (Drill Traces) coloured by Total S (%) – E East Final Pit Outline (Red), SIM Unit (green line).

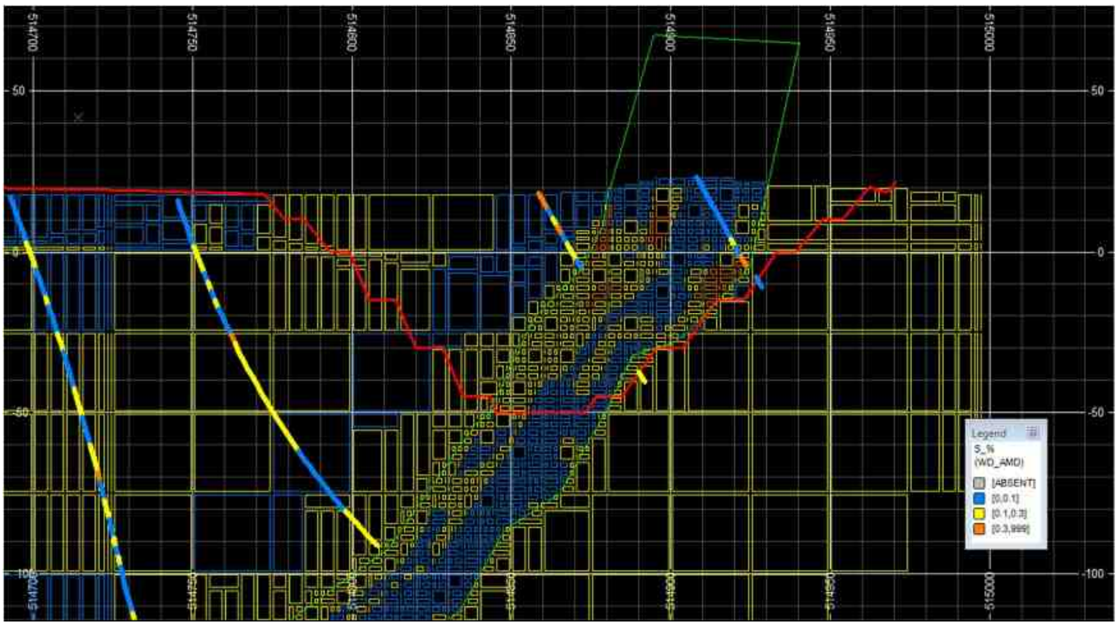


Figure 3 W-E Cross Section (8,325,000 mN) – Block Model and HXRF data (Drill Traces) coloured by Total S (%) – E East Final Pit Outline (Red), SIM Unit (green line).

F Pits (F East & F West 1 to 4) Block Model Comparison – Total S (%)

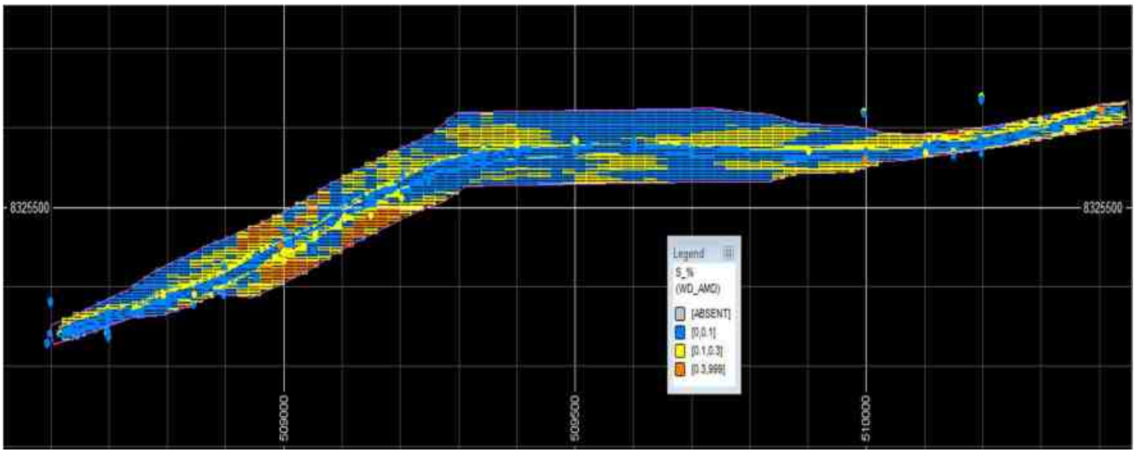


Figure 4 Plan View (-30 mRL) – Block Model and LXRF data (large solid dots) coloured by Total S (%) – F East Final Pit Outline (Purple)

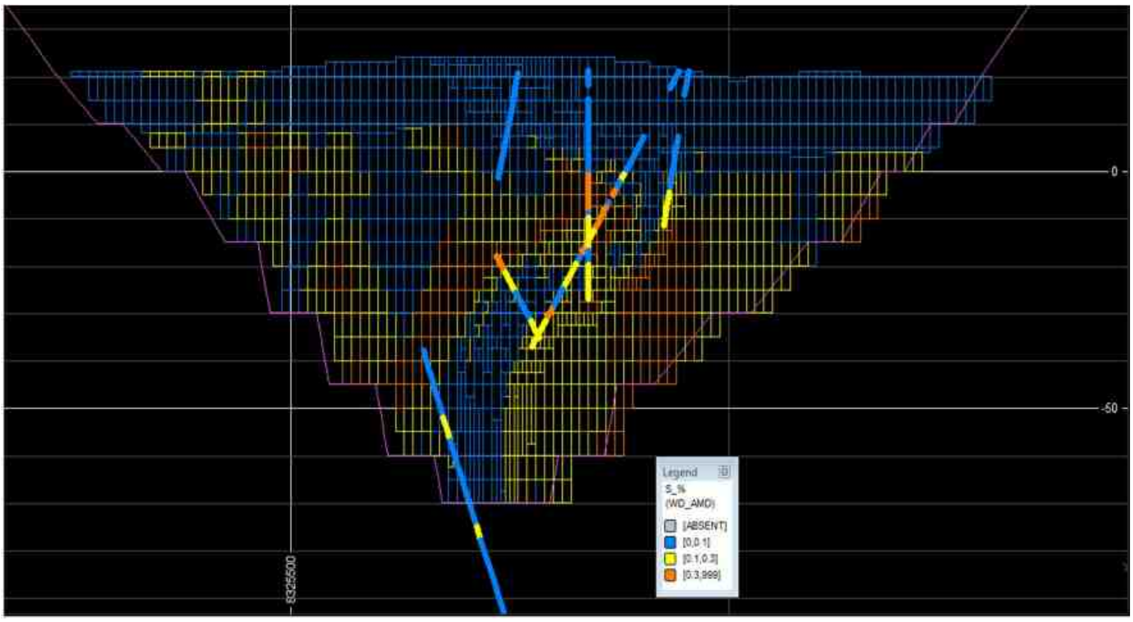


Figure 5 N-S Cross Section (509,000 mE) – Block Model and LXRF data (Drill Traces) coloured by Total S (%) – F East Final Pit Outline (Purple).

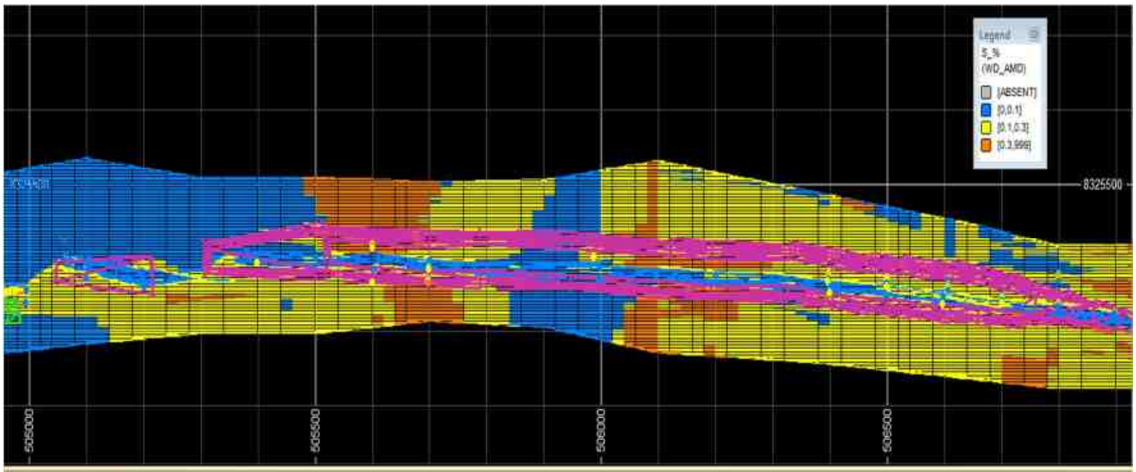


Figure 6 Plan View (5 mRL) – Block Model and LXRF data (large solid dots) coloured by Total S (%) – F West 1 Pit Outline (Purple)

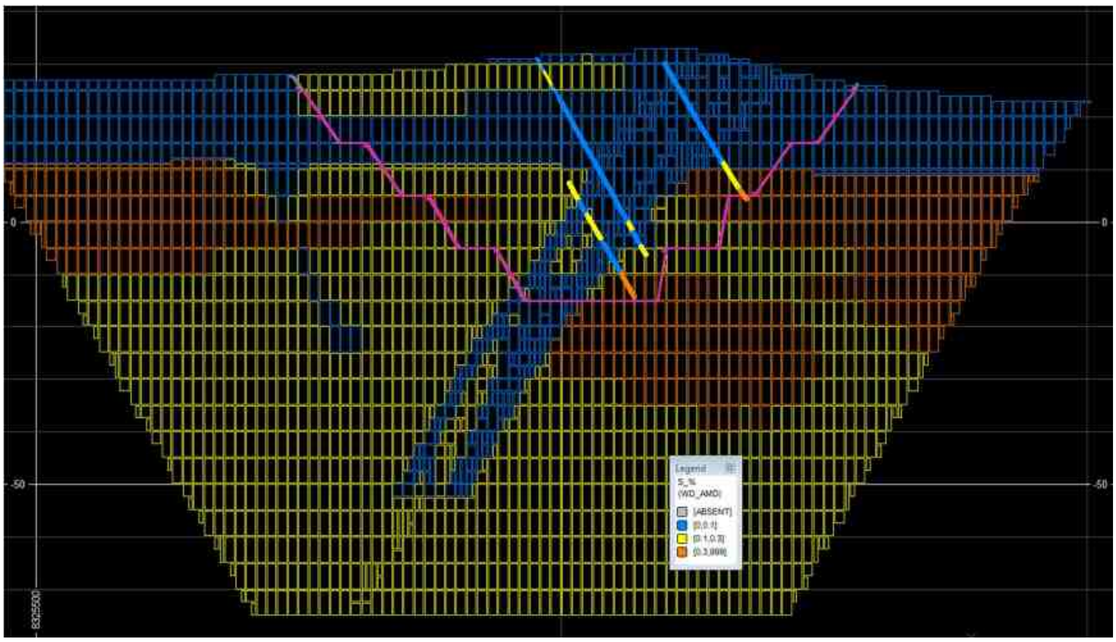


Figure 7 N-S Cross Section (505,700 mE) – Block Model and LXRF data (Drill Traces) coloured by Total S (%) – F West 1 Pit Outline (Purple).

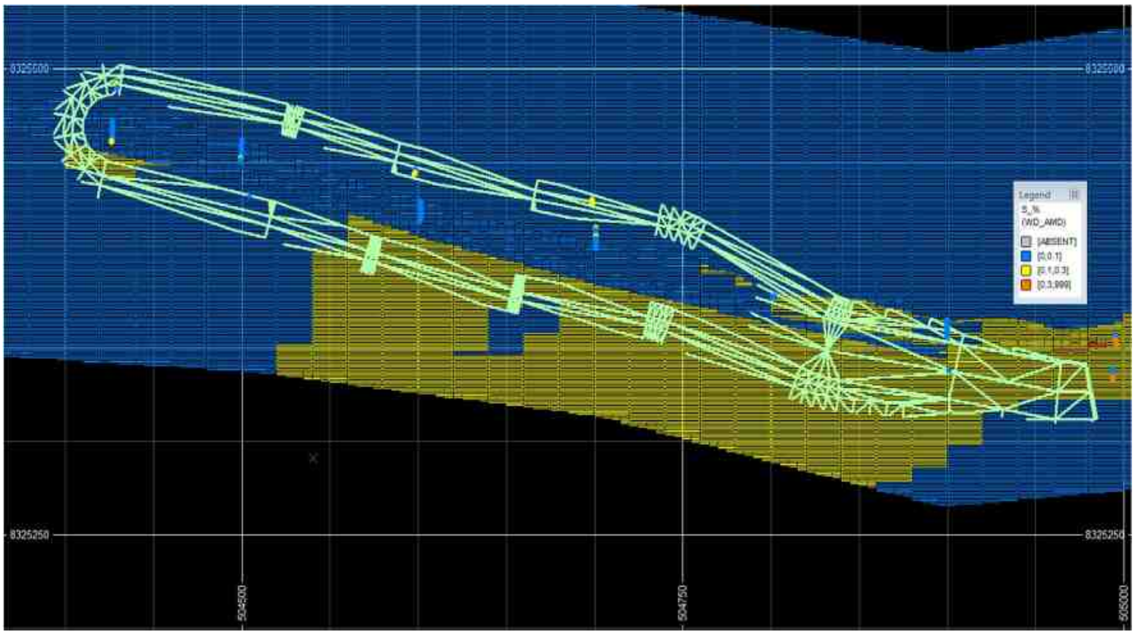


Figure 8 Plan View (5 mRL) – Block Model and LXRF data (large solid dots) coloured by Total S (%) – F West 2 Pit Outline (Lt. Green)

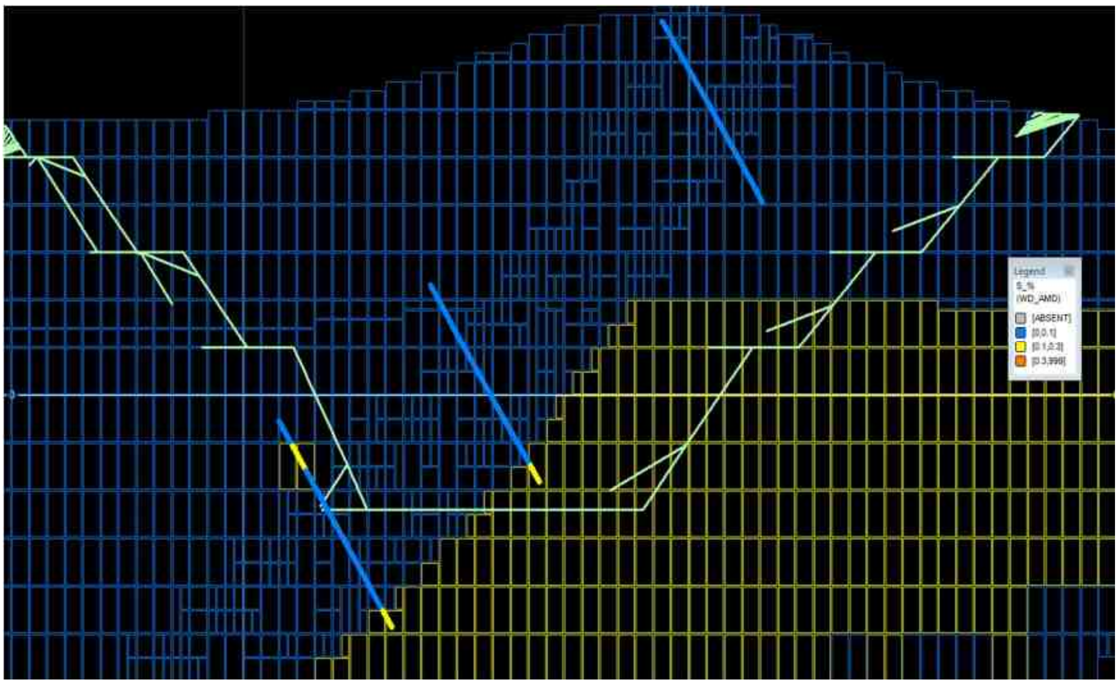


Figure 9 N-S Cross Section (504,600 mE) – Block Model and LXRF data (Drill Traces) coloured by Total S (%) – F West 2 Pit Outline (Lt. Green).

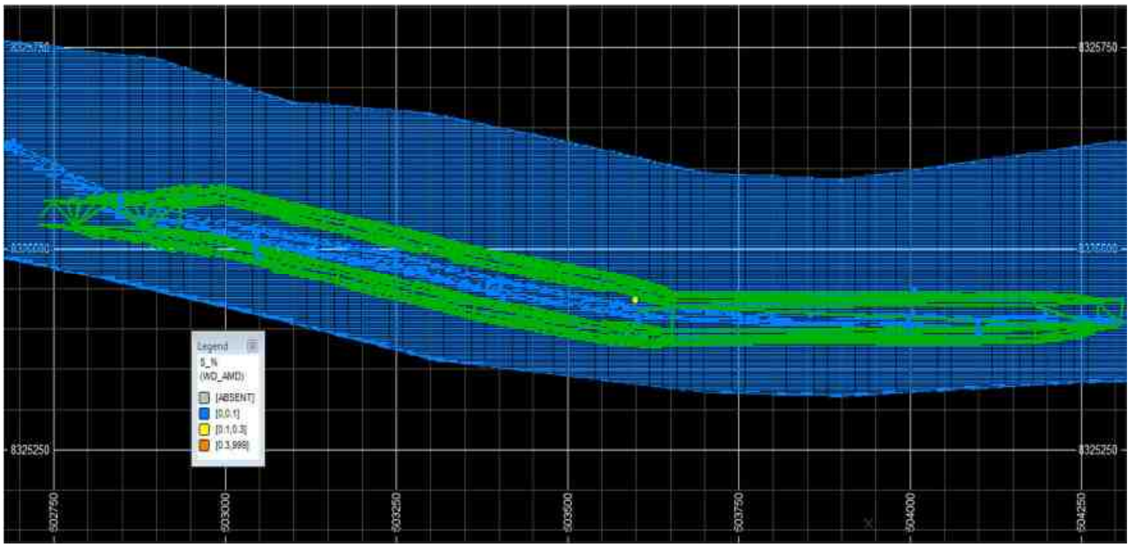


Figure 10 Plan View (20 mRL) – Block Model and LXRF data (large solid dots) coloured by Total S (%) – F West 3 Pit Outline (Green)

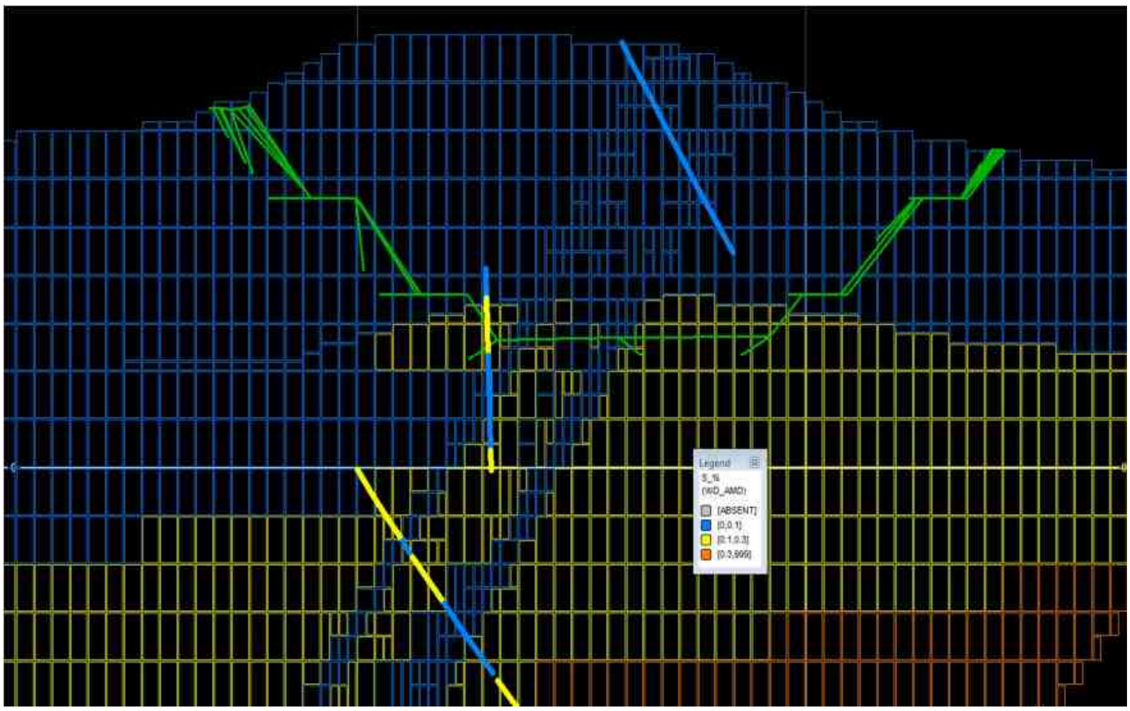


Figure 11 N-S Cross Section (503,600 mE) – Block Model and LXRF data (Drill Traces) coloured by Total S (%) – F West 3 Pit Outline (Green).

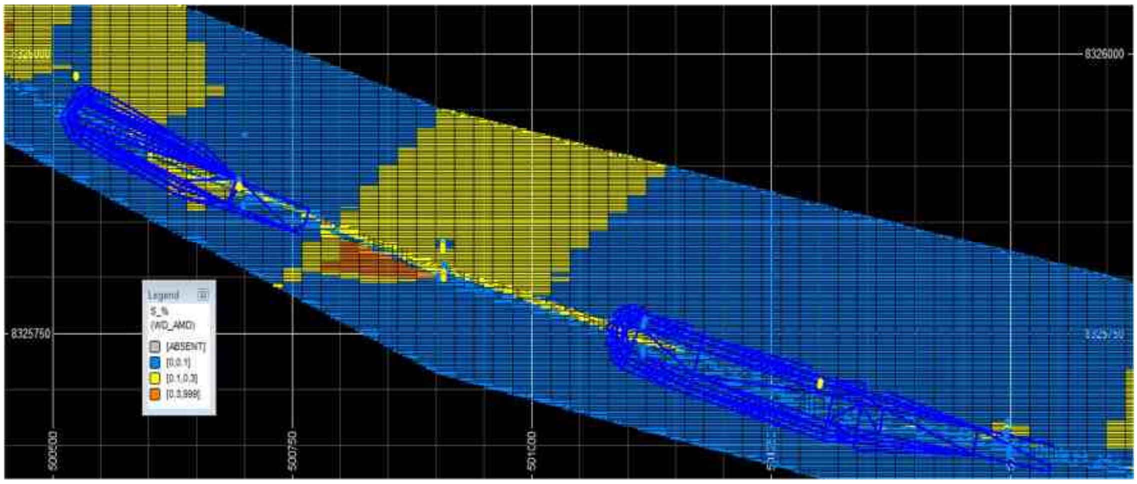


Figure 12 Plan View (20 mRL) – Block Model and LXRF data (large solid dots) coloured by Total S (%) – F West 4 Pit Outline (Blue)

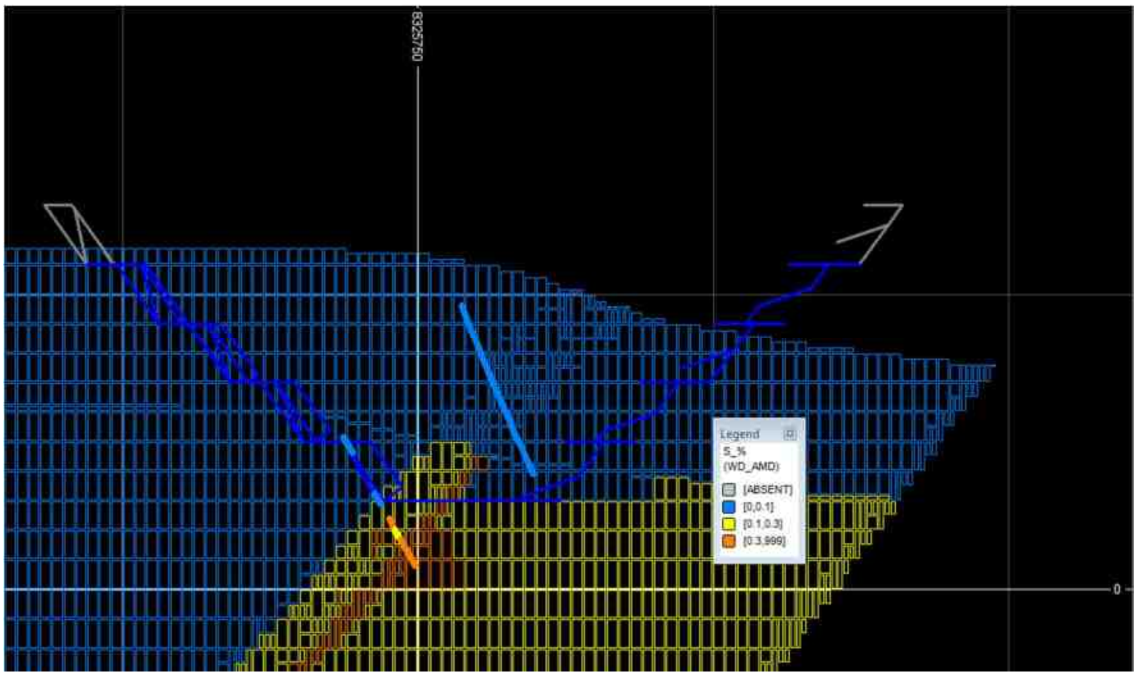


Figure 13 N-S Cross Section (501,100 mE) – Block Model and LXRF data (Drill Traces) coloured by Total S (%) – F West 4 Pit Outline (Blue).

Correlation of geochemical data sets

In order to correlate the data sets provided, LXRF data was correlated against laboratory ABA data (where the same data sample was used).

Data was compared by direct linear correlation or by Quantile – Quantile (Q-Q) Plots. The Q-Q Plot application is meant to compare the distribution of a variable with a distribution of another variable. For each selected variable, the quantiles from its distribution (calculated using the cumulated histogram) are plotted on a graphic (along the vertical axis) versus the quantiles from a reference distribution (along the horizontal axis).

The Q-Q plot of two similar distributions will be distributed along the first bisector of the graphic. If the two distributions differ, the Q-Q plot will move away from the straight line.

The comparison was only based on data that could be directly compared; therefore, the following datasets were used:

- Laboratory assay XRF to laboratory ABA:
    - o Total Sulphur % – 115 samples.

Total Sulfur

Laboratory assay XRF to laboratory ABA

A good correlation was noted using a traditional linear scatter plot (Figure 14). The comparison shows there is a good correlation between the two data sets.

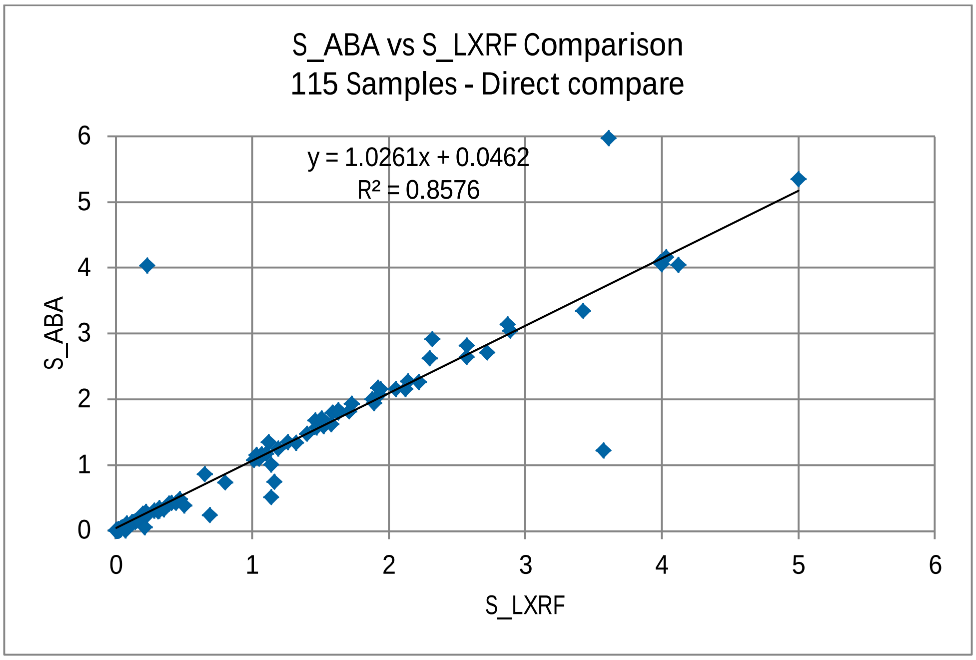


Figure 14 Scatter Plot - Linear Regression of Laboratory assay XRF (LXRF) against Laboratory ABA (ABA) data

The implications for the total sulfur correlations shown above pertain to forward site validation sampling when classifying mineral waste (Appendix B).

Laboratory assay XRF to laboratory ABA

This was not compared, as only Total S data was extracted from the ABA data for spatial comparison work. i.e. there was no comparable ABA data set as the ABA test used the acid neutralising capacity (ANC) test, which is undertaken by titration. It considers all neutralising minerals, not simply calcium.

Conclusions on data set correlation

For total sulfur there was a very good correlation between the ABA and laboratory XRF data. CaO and laboratory titration based neutralising capacity were not compared.

Sample numbers

There is arguably no 'right' number of samples that should be collected; rather, several publications provide guidance toward obtaining a representative sample density. For example, Price (2007), Miller (2013) and the (then) Queensland Department of Mines and Energy (DME) have provided guidance on geochemical sampling numbers / density (see below). The correct number, however, relates to a level of statistical significance for which the AMD risk becomes acceptable based on the proposal.

For example, Price (2007), Miller (2013) and DME (1995) provide the following recommended sample number by major lithological unit as shown below in Equation 1.

Equation 1: $n = 25 \times \sqrt{x}$.

(Where x = Million tonnes (MT) of material per major lithological unit).

Therefore, and based on the above formula, a rule of thumb to be quasi-representative is around 250 samples per 100 MT of material per major lithology. This is referred to herein as 'order of magnitude' sampling (see below). At Roper Bar, the three major lithological units are KYM, SIM and MSM.

With regard to sampling densities, DITR (2007) recommend that at pre-feasibility stage; 'Several hundred representative samples of high and low grade ore, waste rock and tailings should be collected for geochemical test work. i.e. Sufficient samples to populate a block model with a reliable distribution of net acid production potential (NAPP) data on ore, waste and wallrock'.

Further, DITR (2007) recommend that at feasibility stage, 'Improve density of NAPP data for block model if necessary, and conduct sufficient NAG test work to cross check NAPP data for key lithologies. If there are still insufficient data to assess AMD potential and provide a convincing management plan for approval, additional sampling, test work and refinement of block models will be required.

Three approaches were used to assess sampling densities at Roper Bar to determine if an appropriate number of samples have been collected. Each is discussed below.

Order of magnitude sampling

The total number of laboratory assay XRF and ABA samples used in the geochemical assessment (Appendix A) of this document were shown in Appendix A. Table 1 below shows:

- The total approximate tonnes of each of the three main geological units planned to be mined over the life of the DSO project;
- The approximate sampling density required according to the equation above to be representative, based on the total approximate tonnes of each geological unit; and
- The actual XRF (laboratory assay) and ABA total sulfur sample numbers used to undertake the preliminary and detailed geochemical characterisation sections within this document (Appendix A).

Table 1 Total sulfur sampling densities (E East and F East only)

Geological unit	Approx. final DSO Project mined tonnes	Approx. sample number required[1]	Actual total S sample number (LXRF)[3]	Actual total S sample number (ABA)[4]

	(MT)			
KYM	25.2	125	5,433	50
SIM	27.3	131	14,380	104
MSM	42.4	163	4,643	23
Total	**94.8**	**419**	**24,456**	**177**[2]

1: Based on the equation shown above for F East and E East pits only – excludes F West pits so volumes may vary from Appendix A.

2: 27 of the 204 ABA samples were from non-mined lithologies and were therefore excluded from Table 1. 175 of the 204 samples were used in the geochemical model.

3: Lab XRF dataset provided by WDRL.

4: Provided by Pendragon (2012).

Based on the data provided in Table 1 above, an appropriate number of laboratory XRF geochemical samples have been collected to undertake the geochemical assessment (Appendix A); however, an insufficient number of laboratory geochemical analyses have been undertaken to undertake. That is to say, that the sample set provided by Pendragon, *on its own*, is insufficiently large to base a statistically confident geochemical assessment upon to inform an AMD risk assessment.

Moreover, not only is the ABA dataset too small in numbers, the initial acid base accounting (ABA) mine waste characterisation sampling and analysis completed by Pendragon (2012) (Appendix K of EcOz 2012) for assessing the AMD risk at Roper Bar appears to have been targeted, rather than random. Pendragon (2012) were provided the geological database containing laboratory assay XRF data and focused on samples with higher relative total sulfur concentrations for laboratory ABA testing. This has the effect of skewing the data set and returning higher mean and median total sulfur concentrations than the XRF data set (refer to Table 2 below). This is despite there being good correlation between total sulfur results between the laboratory assay XRF data set and the laboratory ABA data set; when the same samples are compared (this Appendix).

Table 2 Total S (%) mean and median by data set

Data Set	Sample numbers	Mean (%)	Median (%)
Laboratory XRF – E East Model	6,219	0.14	0.08
Laboratory XRF – F East Model	18,237	0.08	0.02
ABA (Pendragon 2012)	177	0.75	0.20

In addition, the 204 ABA samples collected were the total or global dataset, of which a subset of 177 were in the relevant geological groups (KYM, SIM, MSM), of which 60 samples were located within proposed pit shells; a sample size too small on which to attempt geostatistics.

However, the fact that a statistically representative XRF data set was been generated, allowed that XRF dataset to inform the AMD risk assessment (Appendix A). WDR propose to increase statistical confidence in the ABA dataset by collecting additional samples through operations in accordance with the site procedure attached as Appendix B. Moreover, the geochemical risk assessment would be routinely updated using the increased data set as an input.

Drill hole spacing

Variography

In order to gauge appropriate sample spacing in the laboratory (LXRF) data set was used. Samples were further divided into the following 12 sub-divisions, based on spatial location, oxidation and lithology;

- F Pit Area
    - Oxide – SIM
    - Oxide – KYA
    - Oxide – MSM
    - Fresh – SIM
    - Fresh – KYA
    - Fresh – MSM
- E East Area
    - Oxide – SIM
    - Oxide – KYA
    - Oxide – MSM
    - Fresh – SIM
    - Fresh – KYA
    - Fresh – MSM

Oxidation state (Oxide – combined oxide and transitional material, and Fresh is material below the Top of Fresh oxidation level).

Variography was used to assess the minimal sampling density to represent total sulphur grade continuity. Variogram is used as a generic word to designate the function characterizing the variability of variables versus the distance between two samples.

No sample compositing was used. So in order to reduce the variability and therefore contain any outlier data, and improve the variogram, the data was transformed into Gaussian space using a Hermite polynomial curve-fitting function within the Geovariance Isatis geostatistical software package. Also, no unfolding was applied to the dataset, so the ranges of grade continuity shown will be conservative; and in reality will be longer than portrayed. The models used were E East and F East (Figure 15) as supplied by WDR.

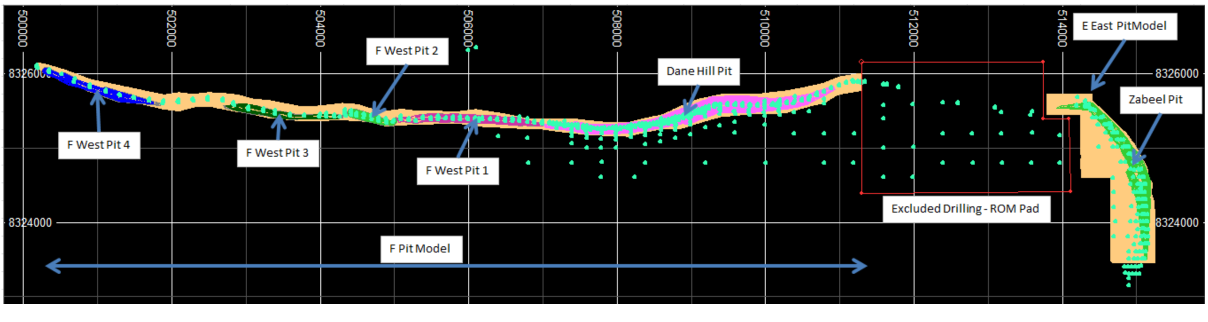


Figure 15 Location Plot of LXRF data – Plan View

Experimental correlograms were calculated and modelled using the Isatis geostatistical package and are shown below.

F Pit Area – SIM Oxide

A total of 2,283 samples were used to represent the F Pit area SIM oxide. Refer to Figure 16 for sample locations in plan view.

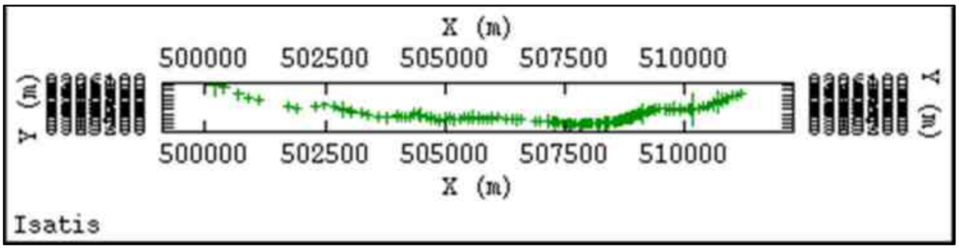


Figure 16 Base Map of LXRF Sample Locations for F Pit area – Plan view

The log-histogram of the data is shown in Figure 17. An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 18.

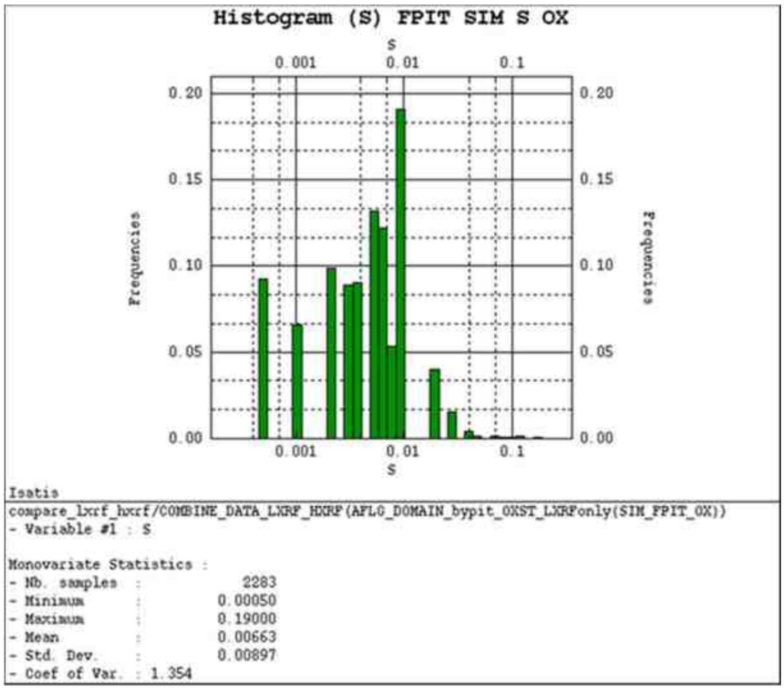


Figure 17 Log-Histogram of LXRF Data

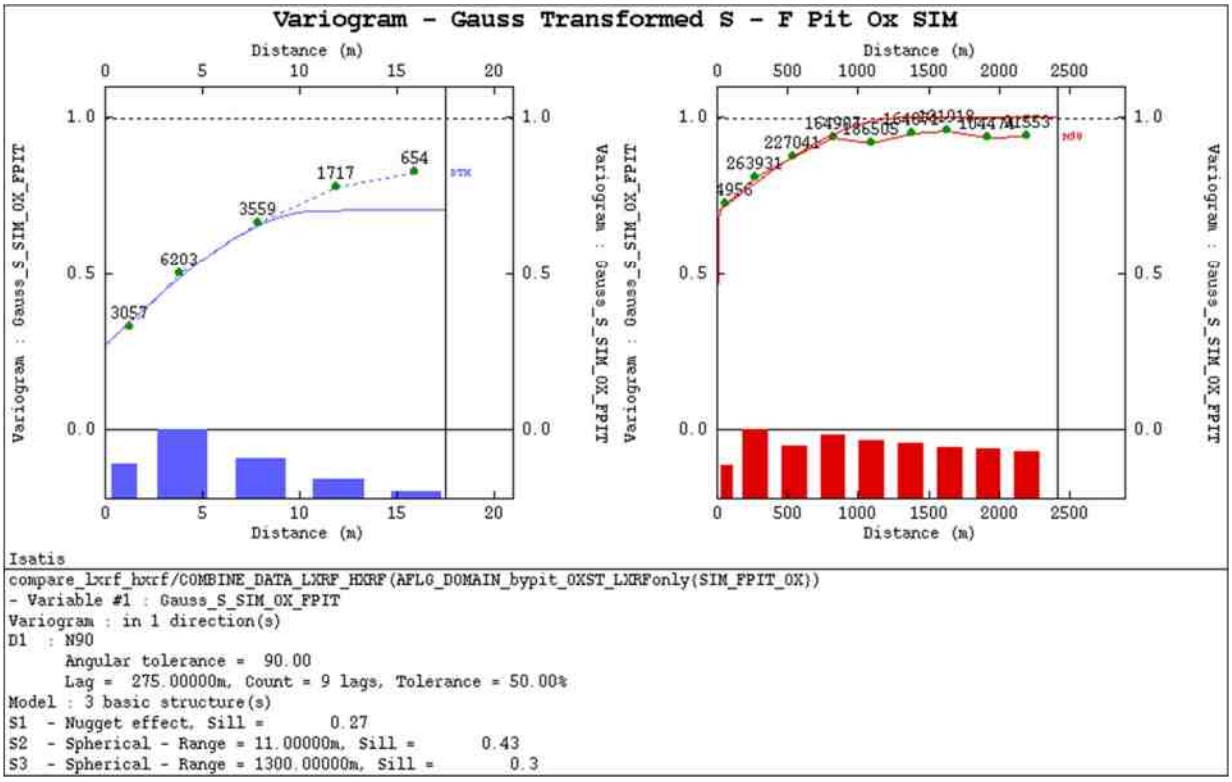


Figure 18 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a low relative nugget of 27%. The short-range structure contributes a significant portion of the non-nugget variance (43%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 1,300 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

F Pit Area –KYA Oxide

A total of 695 samples were used to represent the F Pit area KYA oxide. Refer to Figure 19 for sample locations in plan view. The log-histogram of the data is shown in Figure 20.

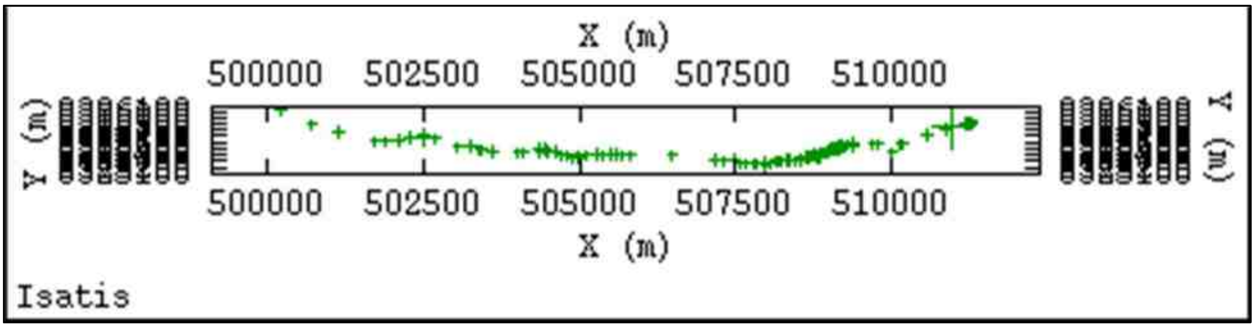


Figure 19 Base Map of LXRF - Sample Location – Plan view

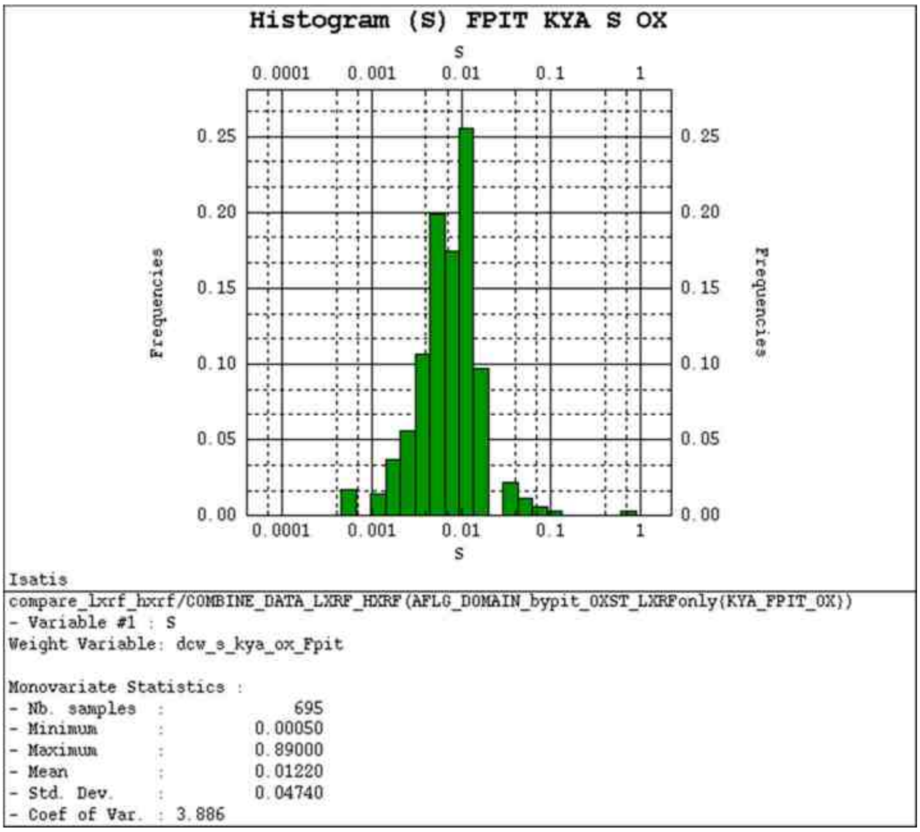


Figure 20 Log-Histogram of Laboratory XRF (LXRF) Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 21.

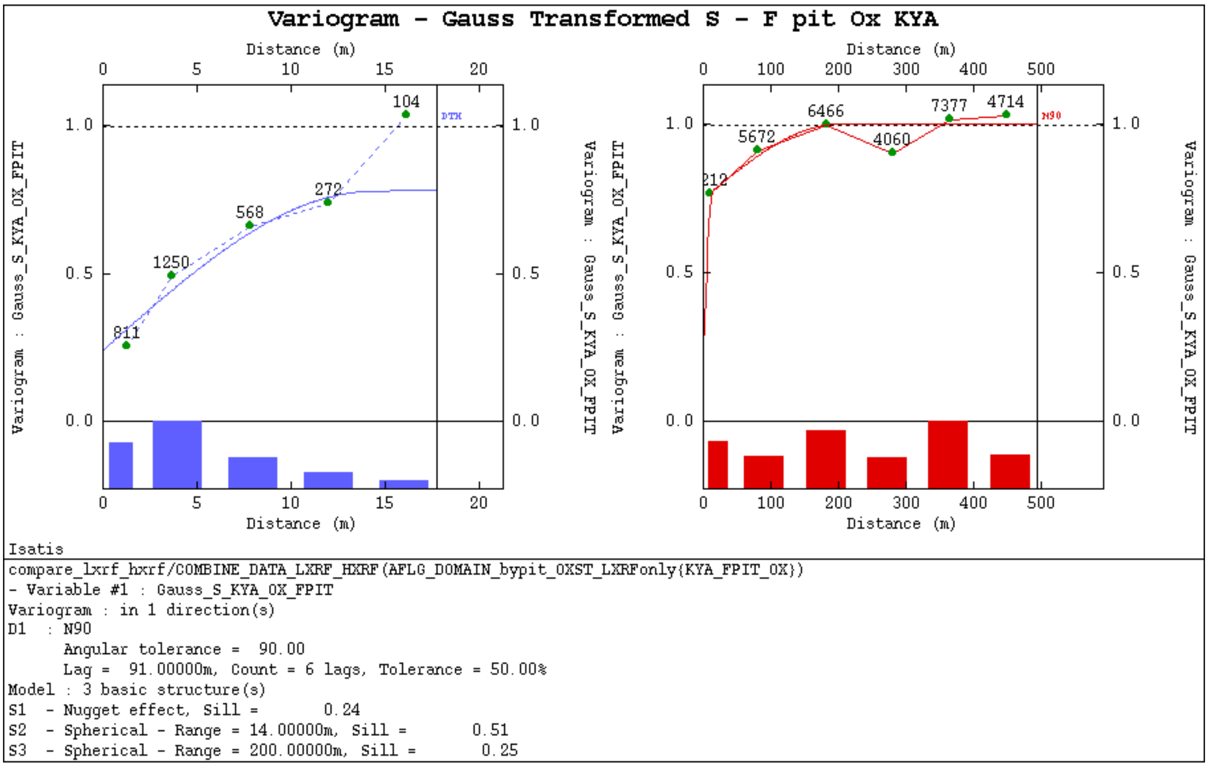


Figure 21 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a low relative nugget of 24%. The short-range structure contributes a significant portion of the non-nugget variance (51%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 200 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

F Pit Area –MSM Oxide

A total of 1,137 samples were used to represent the F Pit MSM oxide zone (Figure 22). The log-histogram of the data is shown in Figure 23.

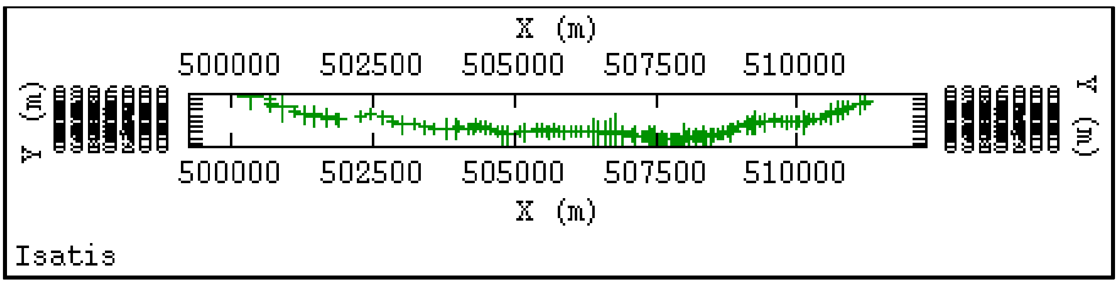


Figure 22 Base Map of LXRF - Sample Location – Plan view

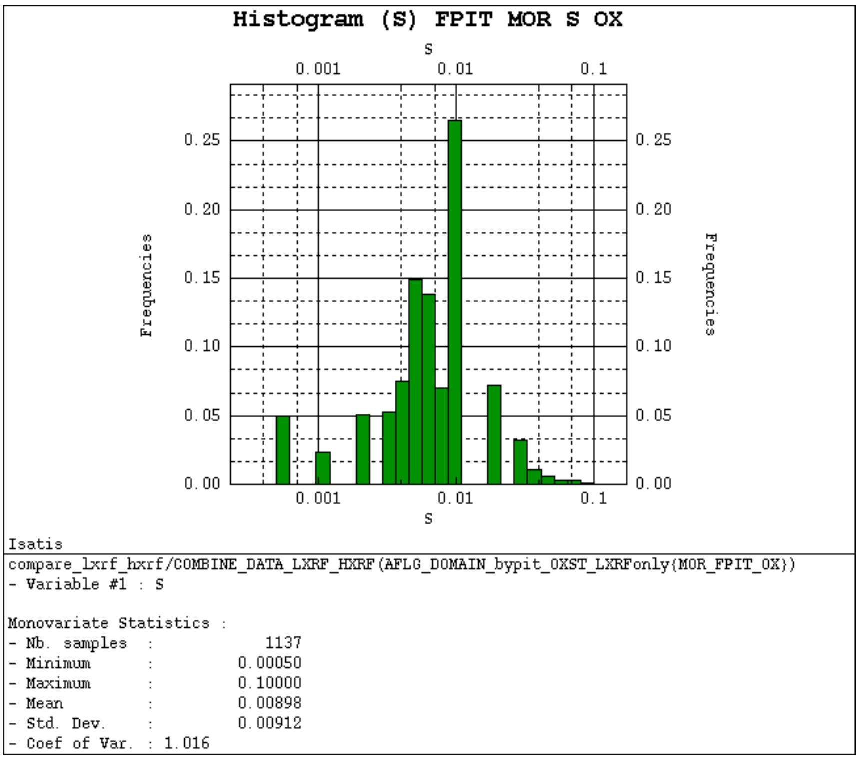


Figure 23 Log-Histogram of LXRF Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 24.

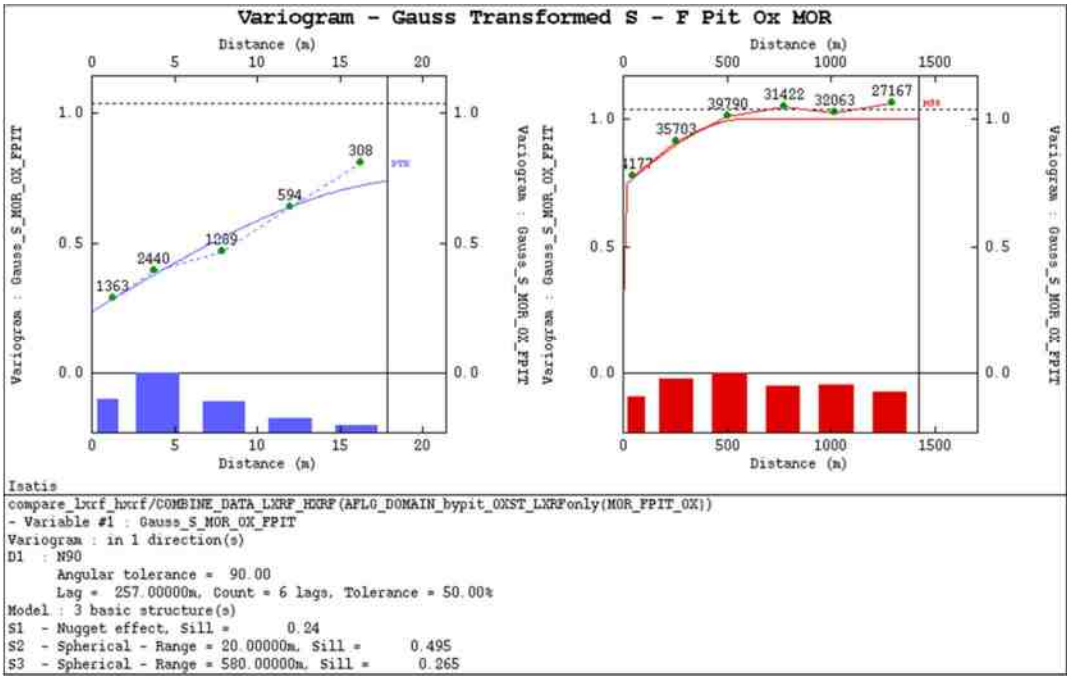


Figure 24 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a low relative nugget of 24%. The short-range structure contributes a significant portion of the non-nugget variance (49.5%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 580 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

F Pit Area –SIM Fresh

A total of 6,876 samples were used to represent the F Pit Area – SIM Fresh (Figure 25). The log-histogram of the data is shown in Figure 26.

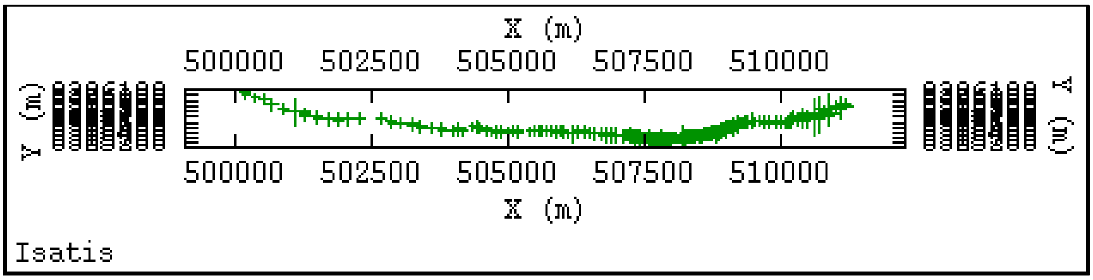


Figure 25 Base Map of LXRF - Sample Location – Plan view

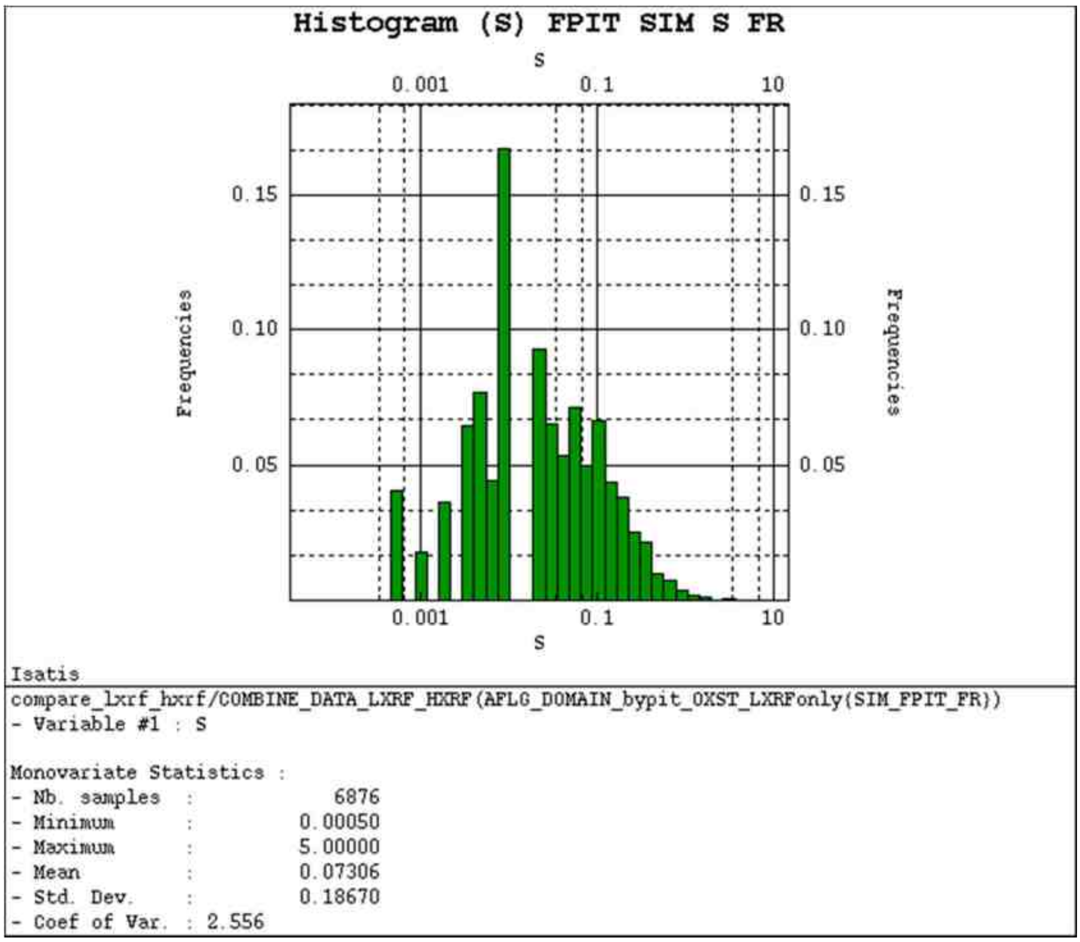


Figure 26 Log-Histogram of Laboratory XRF (LXRF) Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 27.

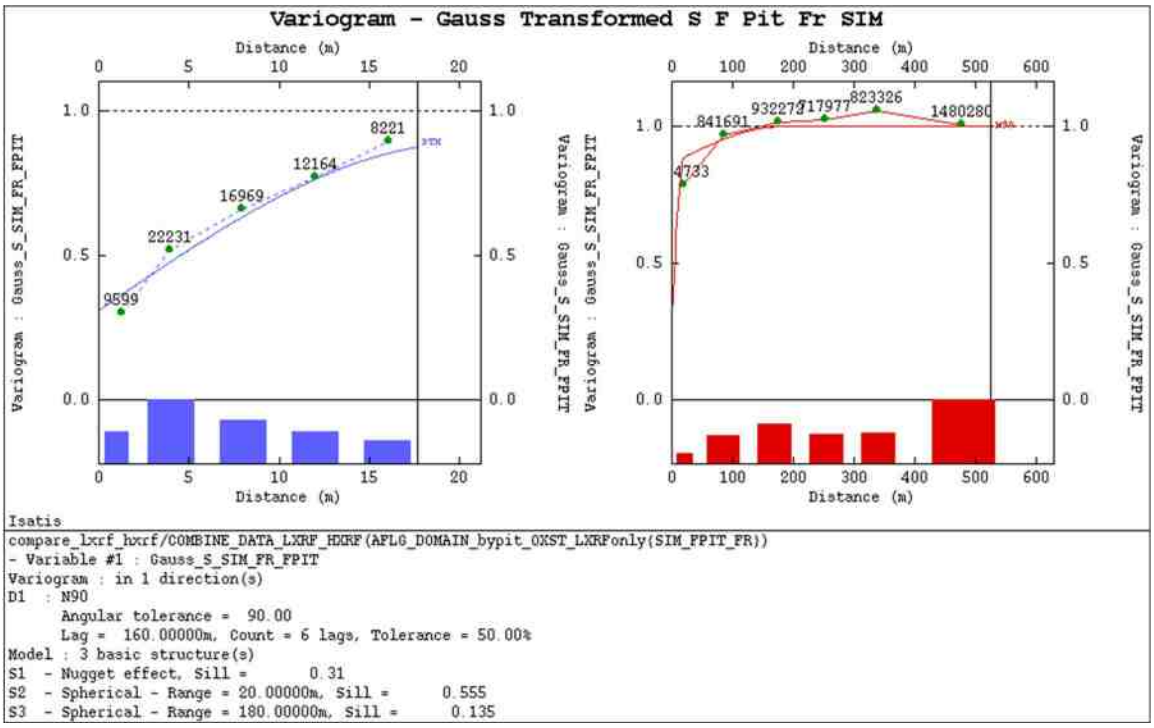


Figure 27 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a low relative nugget of 31%. The short-range structure contributes a significant portion of the non-nugget variance (55.5%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 180 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

F Pit Area –KYA Fresh

A total of 4,398 samples were used to represent the F Pit KYA fresh zone (Figure 28). The log-histogram of the data is shown in Figure 29.

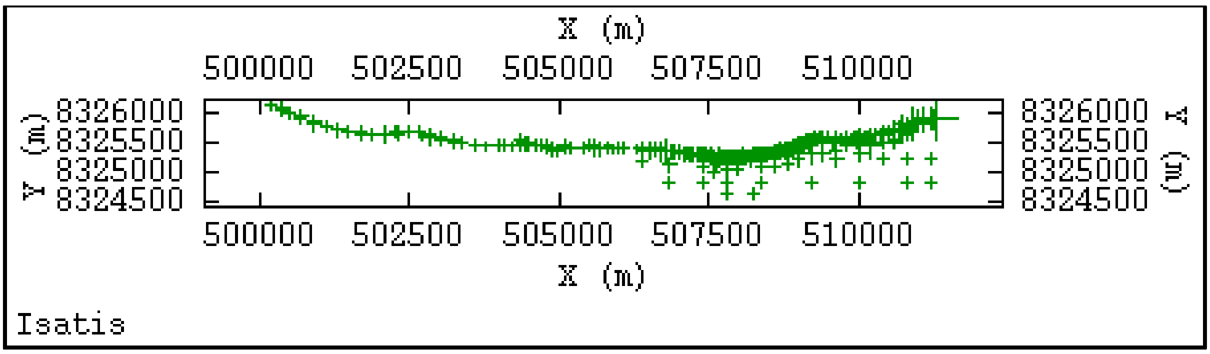


Figure 28 Base Map of LXRF - Sample Location – Plan view

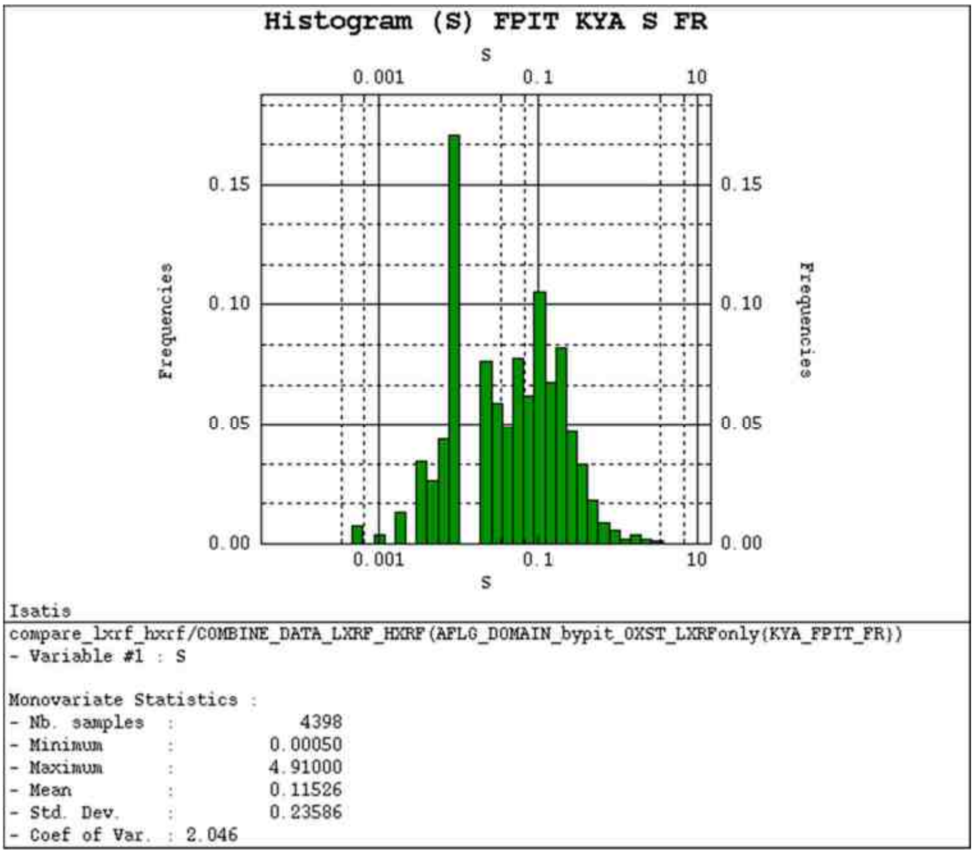


Figure 29 Log-Histogram of LXRF Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 30.

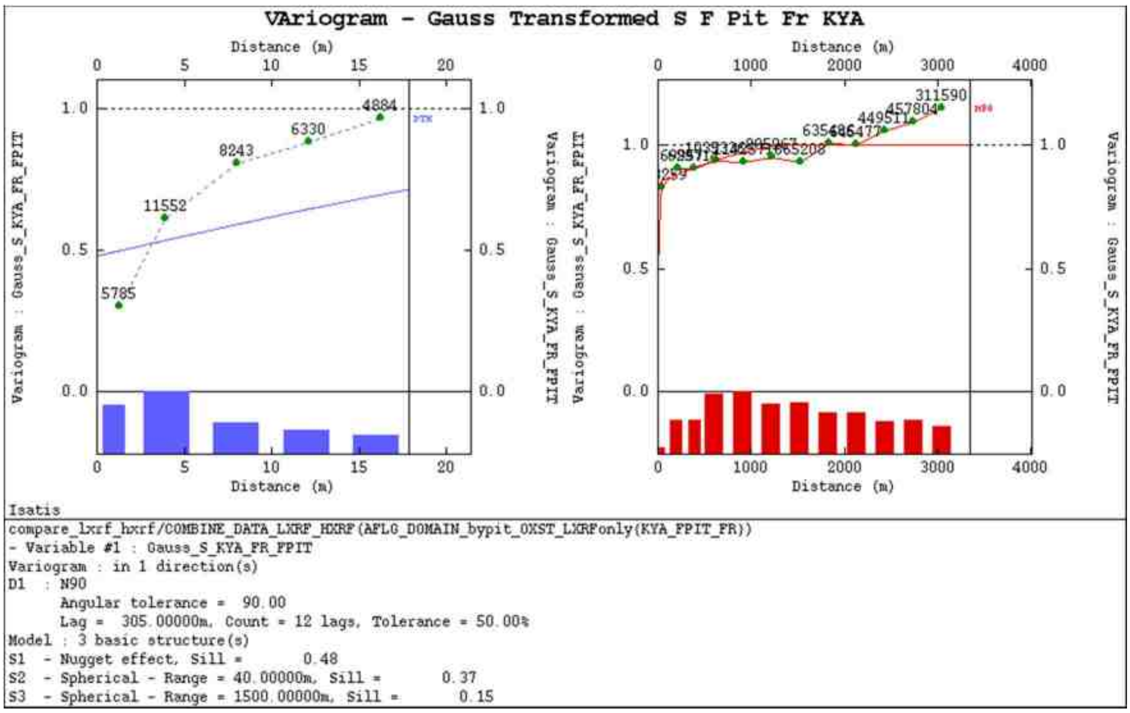


Figure 30 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a moderate relative nugget of 48%. The short-range structure contributes a significant portion of the non-nugget variance (37%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 1,500 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

E East Pit Area –SIM Oxide

A total of 1,270 samples were used to represent the E East SIM oxide zone (Figure 31). The log-histogram of the data is shown in Figure 32.

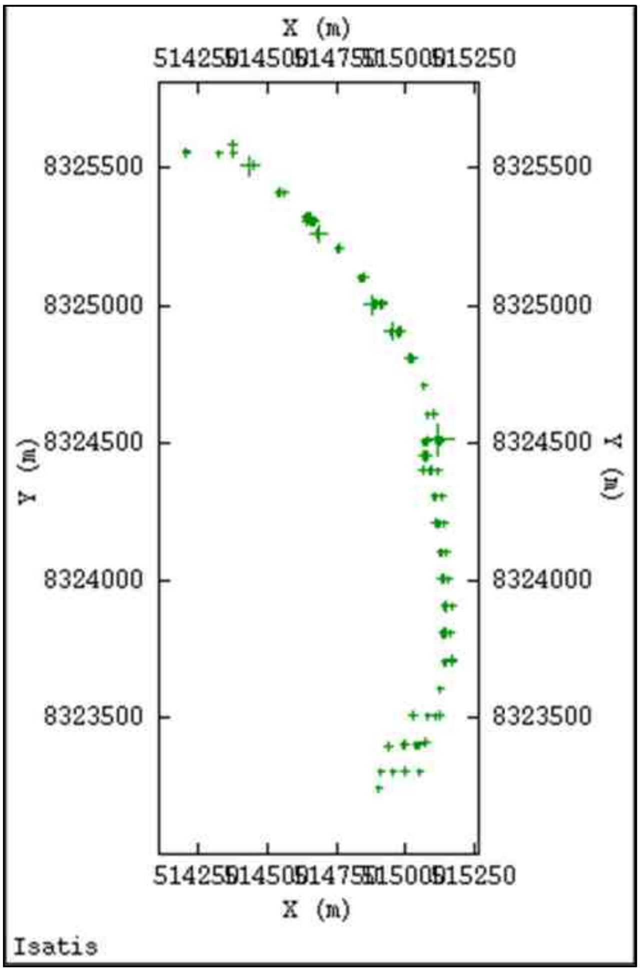


Figure 31 Base Map of LXRF - Sample Location – Plan view

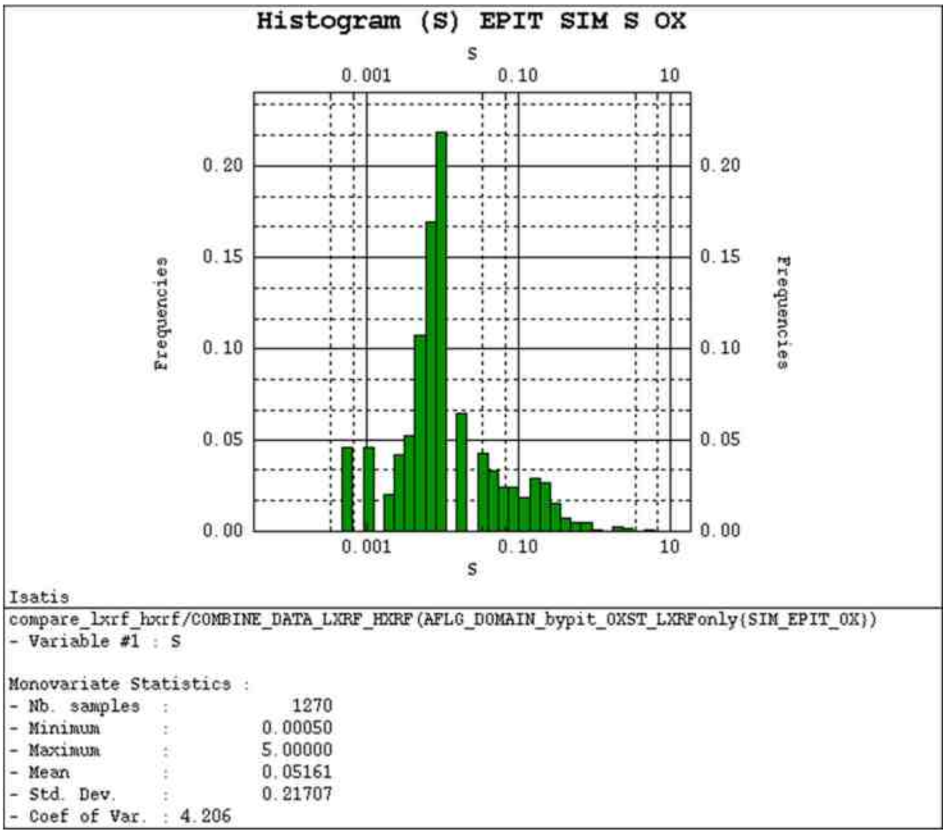


Figure 32 Log-Histogram of LXRF Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 33.

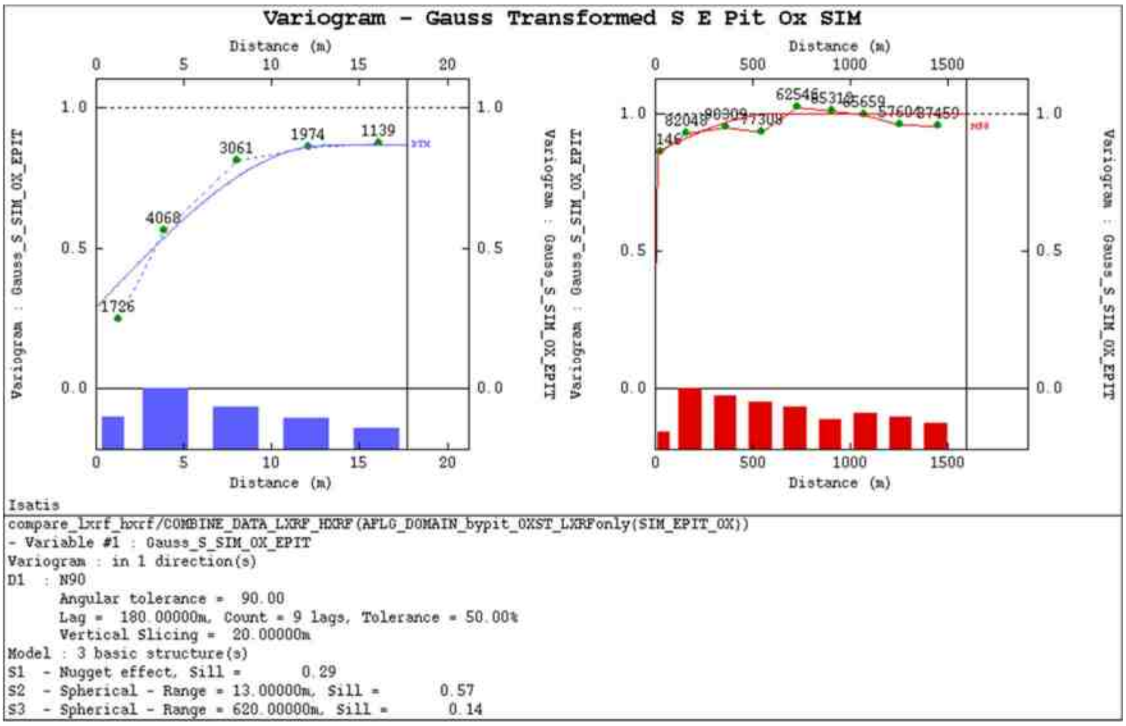


Figure 33 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a low relative nugget of 29%. The short-range structure contributes a significant portion of the non-nugget variance (57%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 620 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

E East Pit Area –KYA Oxide

A total of 131 samples were used to represent the E East KYA oxide zone (Figure 34). The log-histogram of the data is shown in Figure 35.

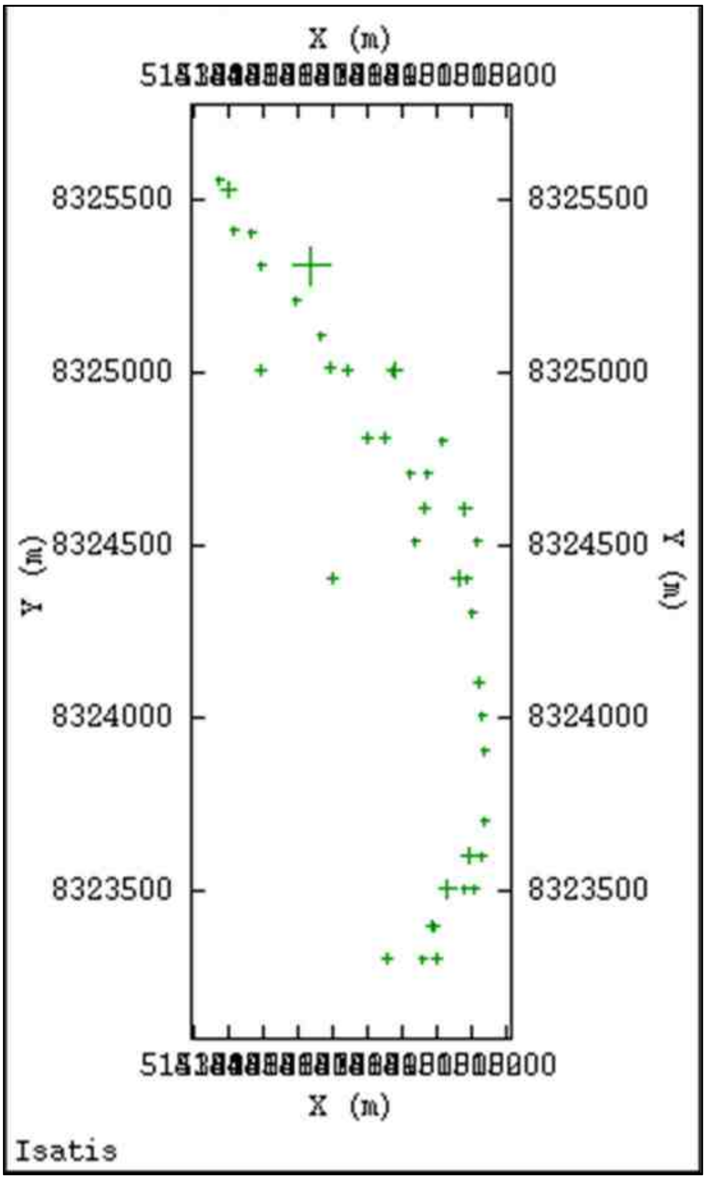


Figure 34 Base Map of LXRF - Sample Location – Plan view

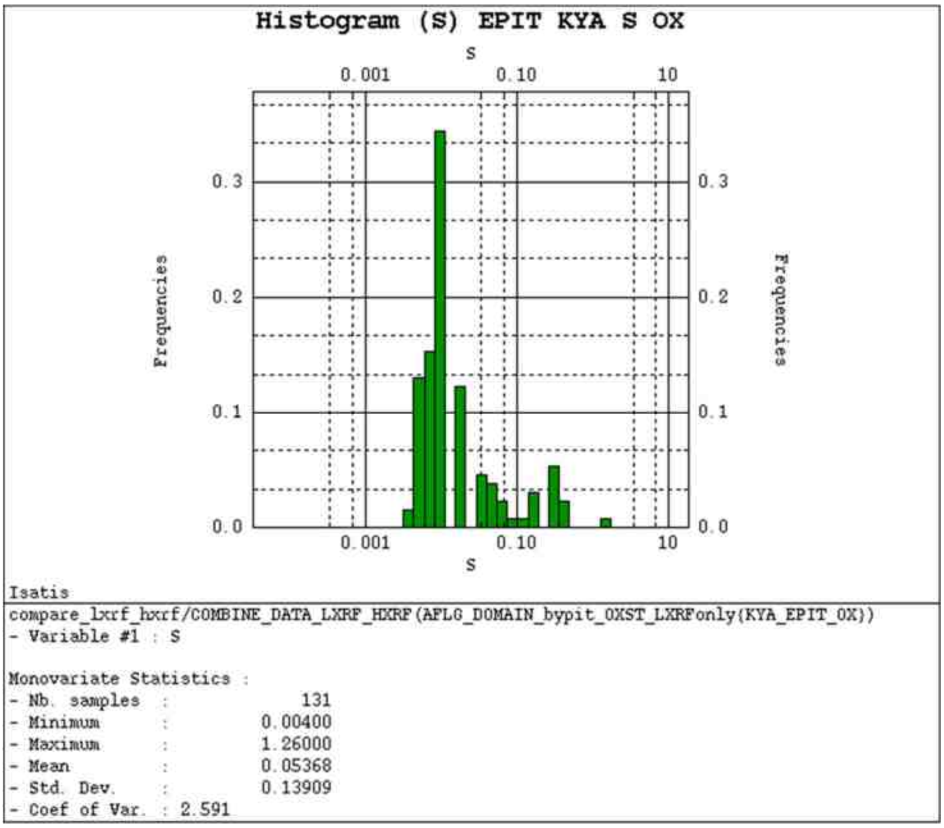


Figure 35 Log-Histogram of LXRF Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 36.

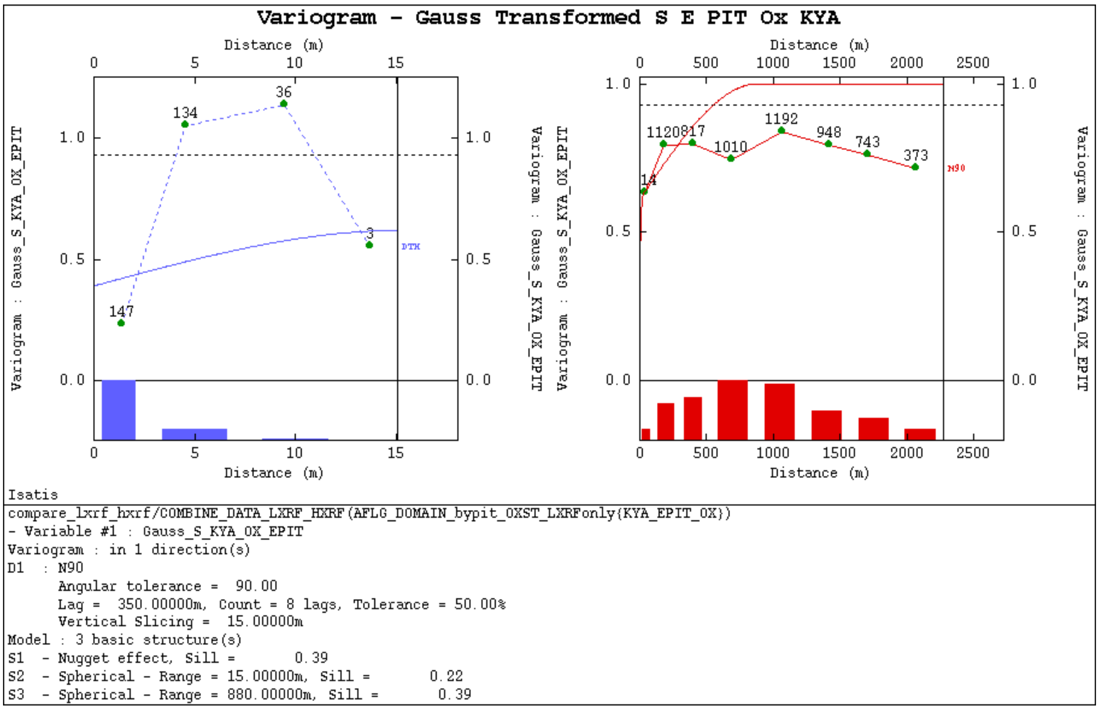


Figure 36 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

Based on the limited amount of samples (131), a poor variogram was generated. It shows a moderate relative nugget of 39%. The short-range structure contributes a significant portion of the non-nugget variance (22%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 880 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

E East Pit Area –MSM Oxide

A total of 88 samples were used to represent the E East MSM oxide zone (Figure 37). The log-histogram of the data is shown in Figure 38.

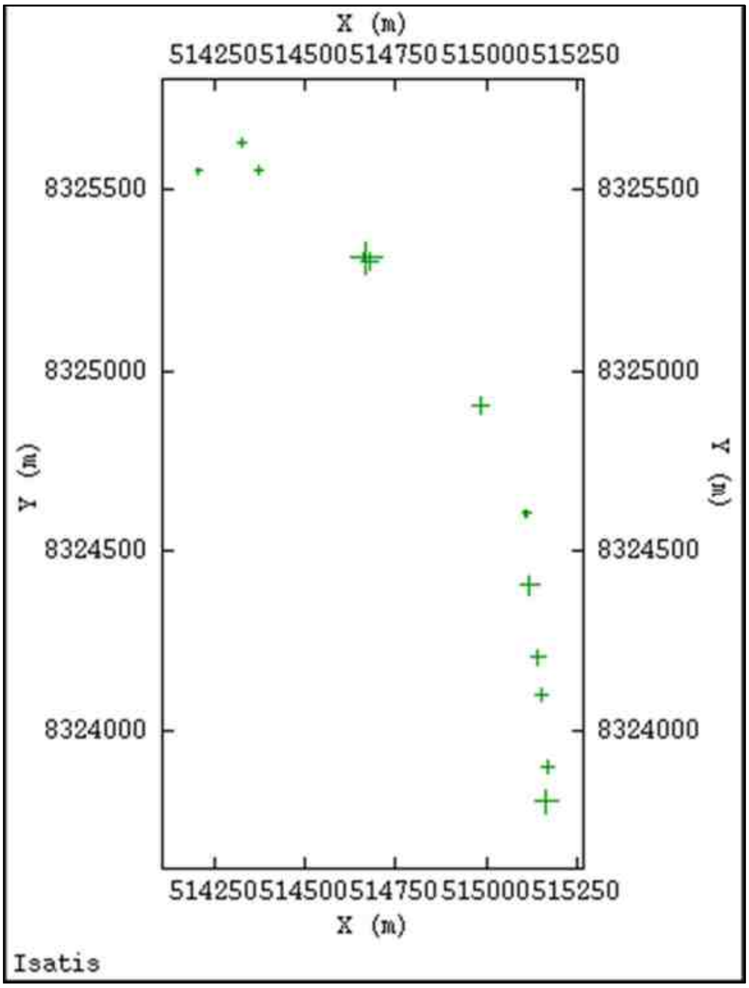


Figure 37 Base Map of LXRF - Sample Location – Plan view

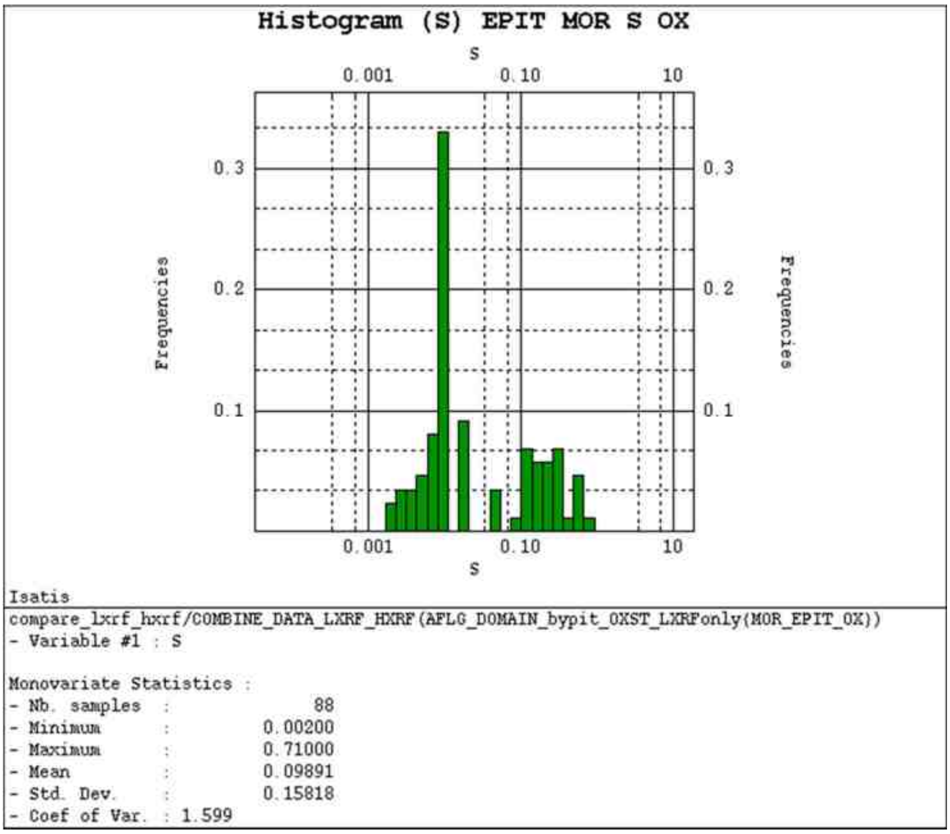


Figure 38 Log-Histogram of LXRF Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 39.

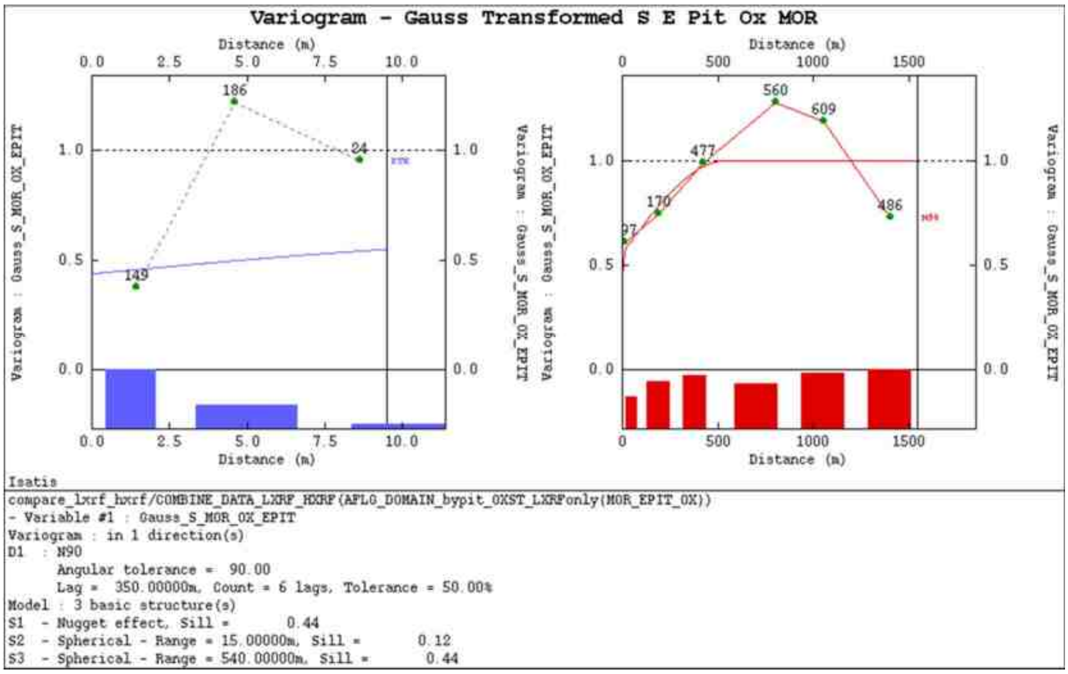


Figure 39 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

Based on the limited amount of samples (88), a poor variogram was generated. It shows a moderate relative nugget of 44%. The short-range structure contributes a small portion of the non-nugget variance (12%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 540 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

E East Pit Area –SIM Fresh

A total of 3,951 samples were used to represent the E East SIM fresh zone (Figure 40). The log-histogram of the data is shown in Figure 41.

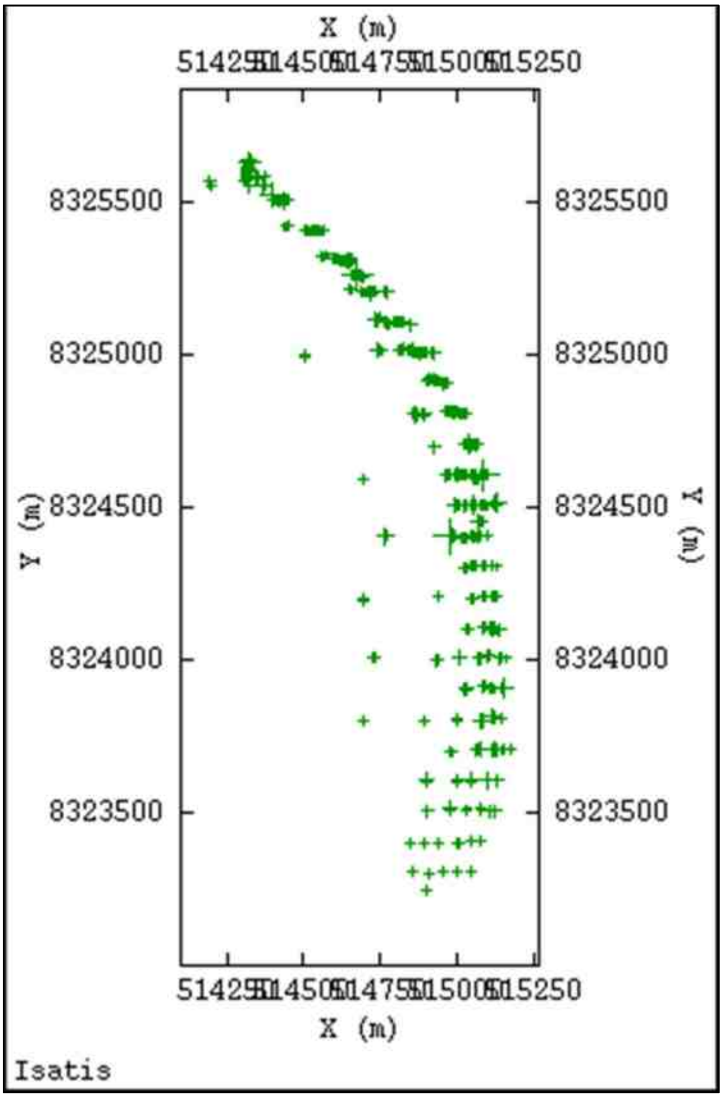


Figure 40 Base Map of LXRF - Sample Location – Plan view

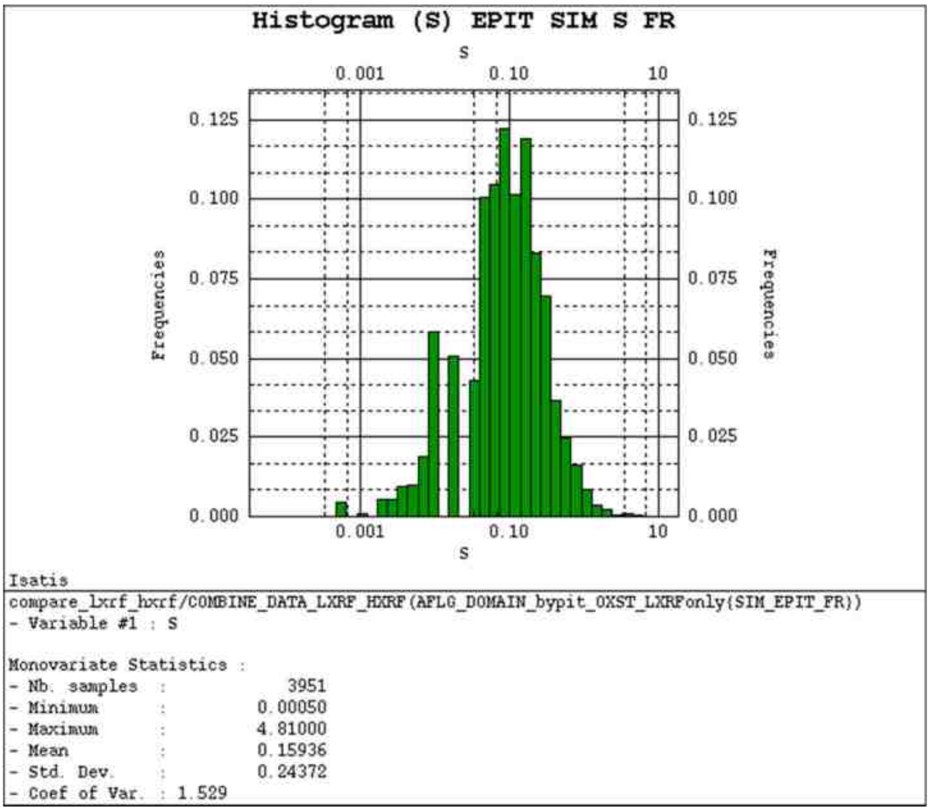


Figure 41 Log-Histogram of LXRF Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 42.

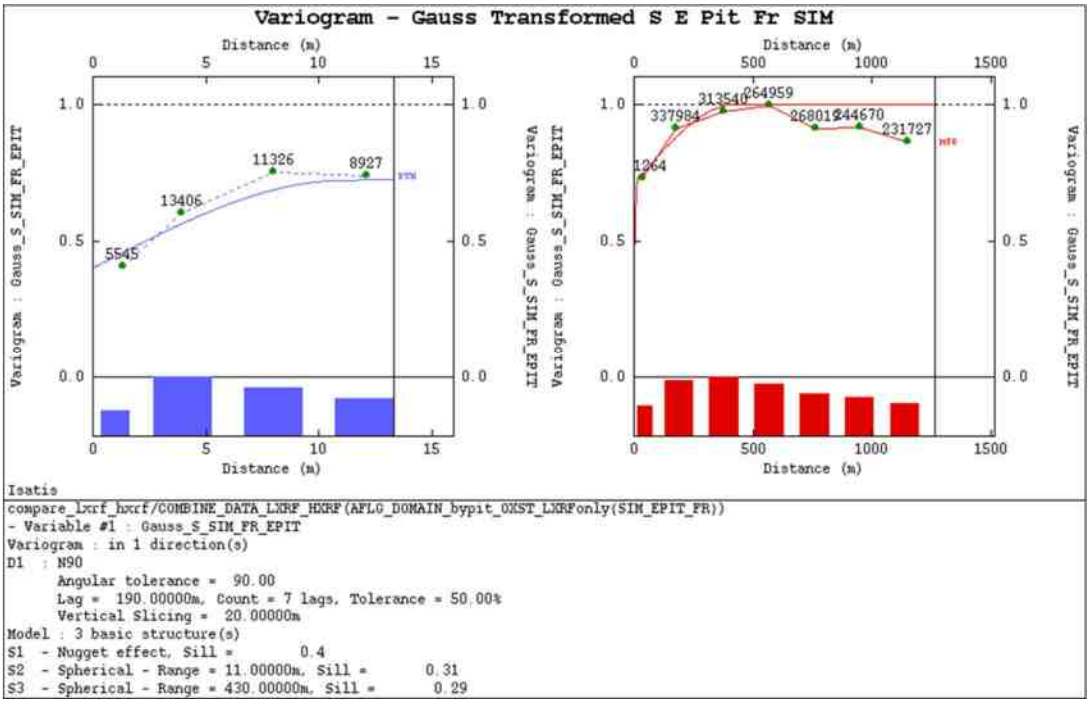


Figure 42 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a moderate relative nugget of 40%. The short-range structure contributes a significant portion of the non-nugget variance (31%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 430 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

E East Pit Area –KYA Fresh

A total of 209 samples were used to represent the E East KYA fresh zone (Figure 43). The log-histogram of the data is shown in Figure 44.

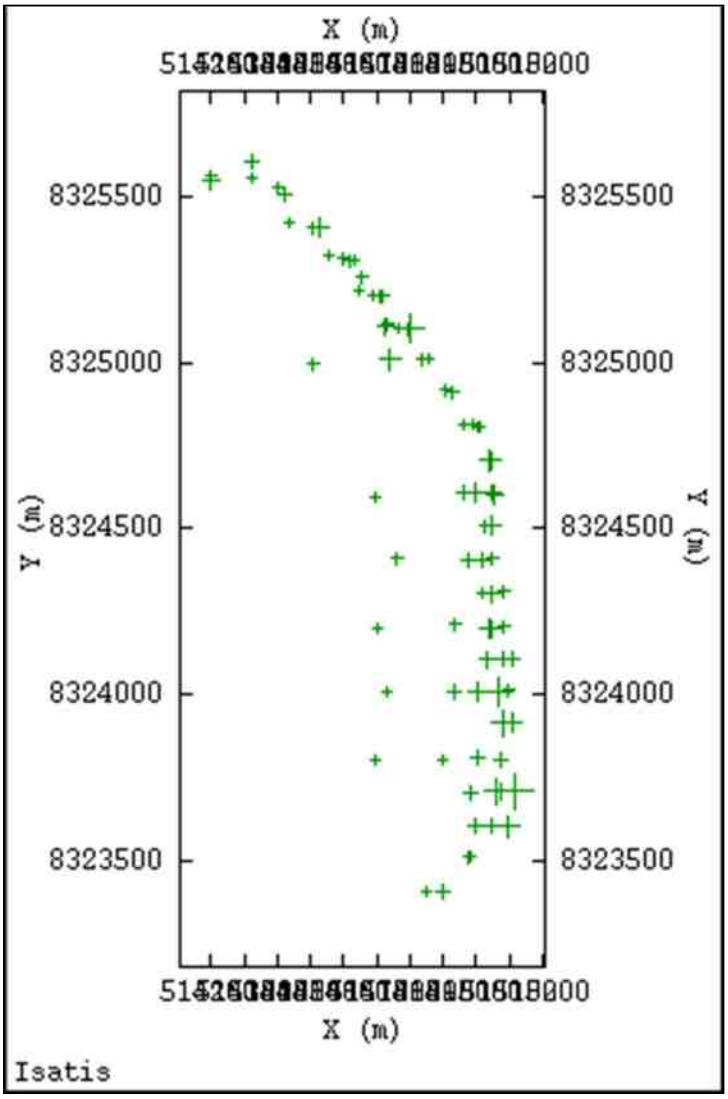


Figure 43 Base Map of LXRF - Sample Location – Plan view

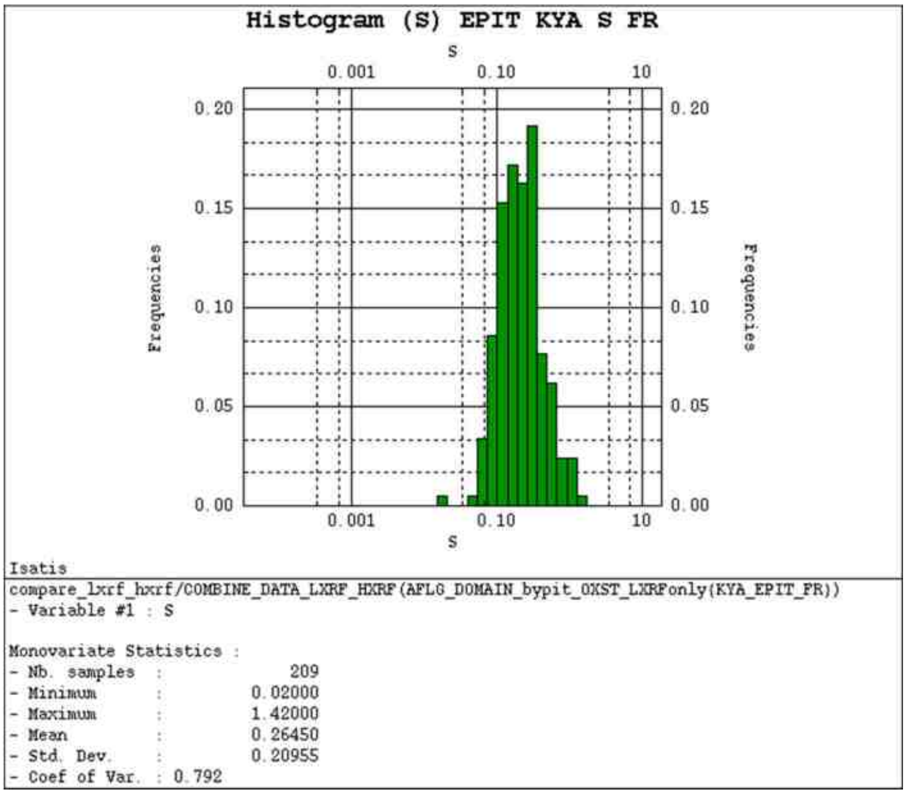


Figure 44 Log-Histogram of LXRF Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 45.

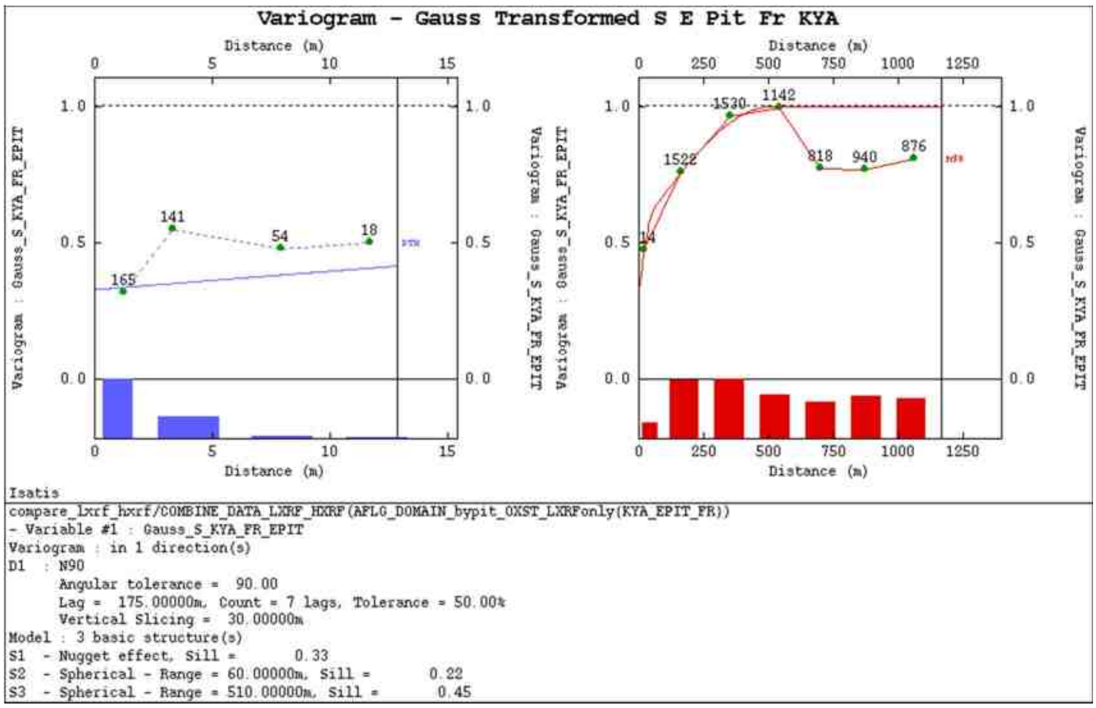


Figure 45 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a moderate relative nugget of 33%. The short-range structure contributes a significant portion of the non-nugget variance (22%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 510 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

E East Pit Area –MSM Fresh

A total of 570 samples were used to represent the E East MSM fresh zone (Figure 46). The log-histogram of the data is shown in Figure 47.

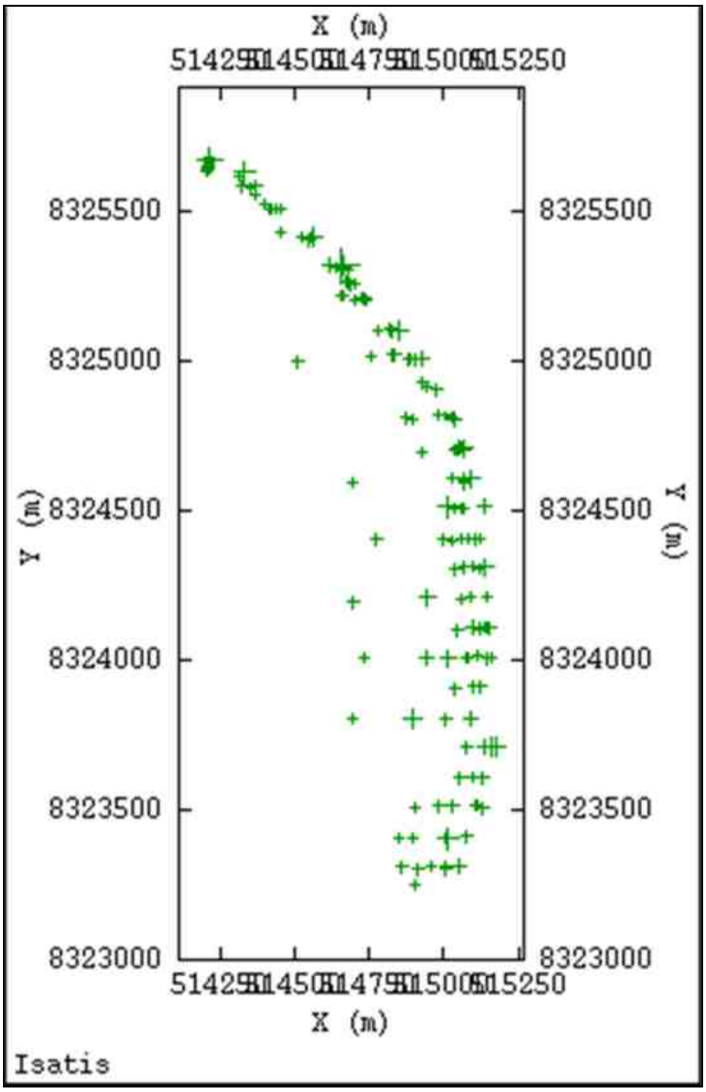


Figure 46 Base Map of LXRF - Sample Location – Plan view

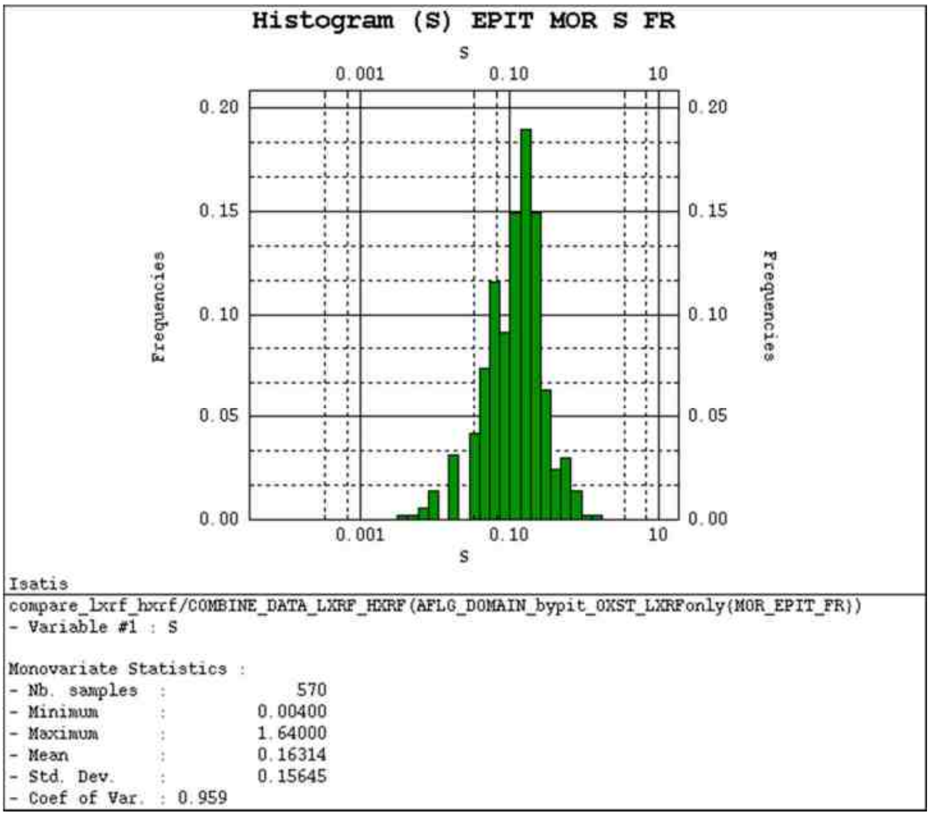


Figure 47 Log-Histogram of LXRF Data

An omnidirectional, 2 structure spherical model was fitted to the Gaussian transformed data, and is shown in Figure 48.

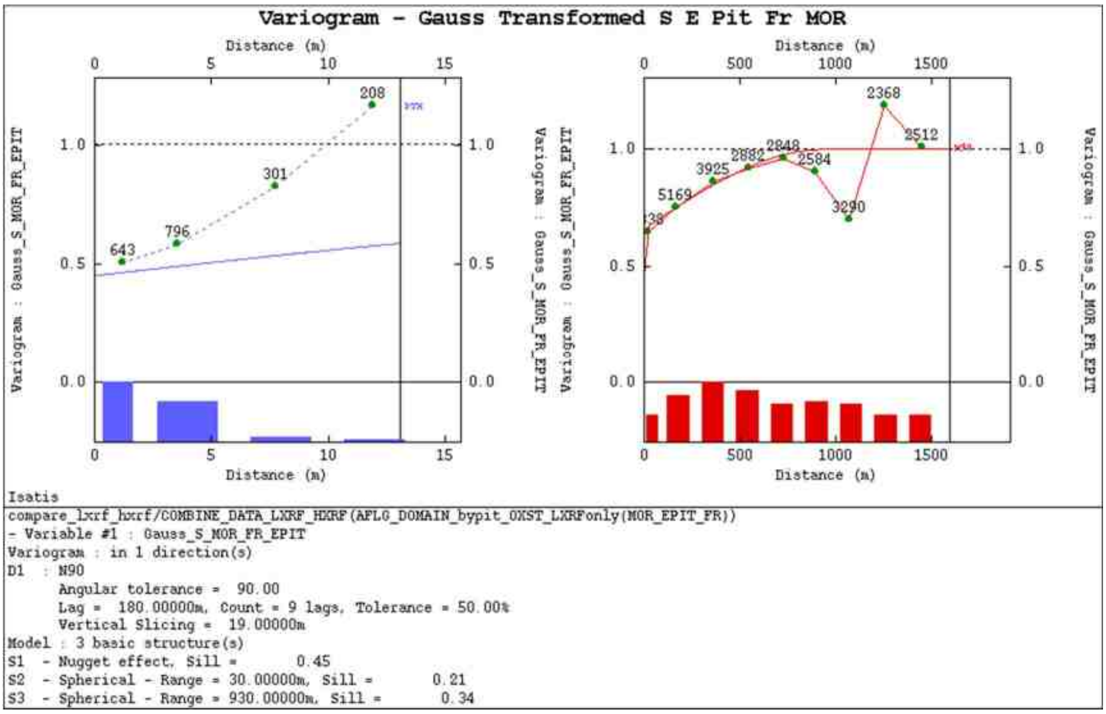


Figure 48 Variogram Model – Gaussian Transformed Data (Left – down-hole variogram / Right - isotropic variogram)

It shows a moderate relative nugget of 45%. The short-range structure contributes a significant portion of the non-nugget variance (21%) and has a range approximating the cross-strike drill spacing of 20 - 30 m. The overall range is 930 m, which is in excess of the along strike drill spacing of 150 m to 50 m.

Variogram summary

The spatial variability study showed that the sulphur grade continuity has been adequately represented by the sample density of the LXRF data set. The LXRF data has been collected on an approximate 100 m section lines along strike in the E East Area and 150 m section lines or better along strike, at the F East Area; well within the limits shown in the variogram study. Refer to Table 3.

Table 3 Summary of Variography Ranges Estimated for Sulphur by Region

Region	Number of Samples	Variogram Range - Sulphur
F Pit Area – SIM Oxide	2,283	1,300 m
F Pit Area – KYM Oxide	695	200 m
F Pit Area – MSM Oxide	1,137	580 m
F Pit Area – SIM Fresh	6,876	180 m
F Pit Area – KYM Fresh	4,398	1,500
F Pit Area – MSM Oxide	2,848	910 m
E East Area – SIM Oxide	1,270	620 m
E East Area – KYM Oxide	131	880 m
E East Area – MSM Oxide	88	540 m
E East Area – SIM Fresh	3,951	430 m
E East Area – KYM Fresh	209	510 m
E East Area – MSM Oxide	570	930 m

The spatial variability study showed that the sulphur grade continuity has been adequately represented by the sample density of the LXRF data. The LXRF data has been collected on approximate 100 m section lines at E East, and on 150 m section lines or better at F East and the F West pits; well within the limits shown in the correlogram study.

Conclusions

The geostatistical summary provided herein E shows that the geochemical model provided good spatial correlation between the laboratory XRF dataset and the geological block models.

With regard to data set correlation, for the total sulfur there was a very good correlation between the ABA and laboratory XRF data sets.

The laboratory (ABA) derived NAPP data shows a significantly lower NAPP value in comparison to the estimated (laboratory XRF) assay NAPP value, showing that the assay datasets do not consider all neutralising minerals in their readings, unlike the laboratory ABA titration method.

The spatial variability study showed that the sulphur grade continuity has been adequately represented by the sample density of the laboratory XRF data. The laboratory XRF data has been collected on approximate 100 m section lines at E East, and on 150 m section lines or better at F East and the F West pits; well within the limits shown in the correlogram study.

The order of magnitude sampling assessment showed that an appropriate number of geochemical samples had been collected in the laboratory XRF dataset to undertake a preliminary geochemical assessment (Appendix A). However, an insufficient number of laboratory geochemical samples had been collected to undertake the preliminary geochemical assessment (Appendix A).

That is to say, that the sample set provided by Pendragon, *on its own,* is insufficiently large to base a statistically confident geochemical assessment upon to inform an AMD risk assessment. Therefore, the laboratory XRF assay data set was utilised in combination with the Pendragon (2012) data to ensure a representative data set was used to inform site AMD risk. A forward sampling schedule has been provided to bolster the laboratory (Pendragon) ABA data (including metals) to ensure the AMD risk assessment can be better informed over the life of mine at Roper Bar.

Appendix E: Water Quality Monitoring and Trigger Values

including Memorandum preliminary review of water quality data to derive trigger values suitable for the receiving waters for the Roper Bar Mine (WRM, 2019)

Surface Water Quality

RBSW02								
Analyte	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	42	-	6.0	7.4	8.63	7.0	7.5	7.8
EC (uS/cm)	41	-	3	155	1156	28	98	211
Aluminium (µg/L)	17	20	40	3016	28400	216	640	2546
Arsenic (µg/L)	15	0.5	0.5	0.8	1	0.5	1	1
Iron (µg/L)	18	20	100	1764	6050	378	1355	3088
Manganese (µg/L)	21	5	2	33.5	205	7	15	49
Sulphate (mg/L)	21	0.1	0.7	4	37.4	1	2	3

FE2								
Analyte	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	15	-	4.1	6.5	7.65	5.8	6.9	7.1
EC (uS/cm)	15	-	1749	2499	2895	2301.2	2610	2755
Aluminium (µg/L)	14	20	20	100	580	20	20	76
Arsenic (µg/L)	14	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Iron (µg/L)	14	20	20	171	1080	20	50	268
Manganese (µg/L)	14	5	2100	5303.6	8120	2548	6365	7682
Sulphate (mg/L)	14	0.1	504	826	998	756.6	843	923.8

RBSW04								
Analyte	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	47	-	5.7	7.3	8.68	7.1	7.4	7.8
EC (uS/cm)	45	-	1	131	853	30.9	84	188
Aluminium (µg/L)	20	20	180	2538	9600	640	1450	4400
Arsenic (µg/L)	20	0.5	0.5	1.0	2.5	0.9	1	1
Iron (µg/L)	21	20	180	1979	8650	480	1340	3140
Manganese (µg/L)	27	5	1	28.4	390	4	10	24
Sulphate (mg/L)	29	0.1	1	3	8.8	1	2	3.6

FE3								
Analyte	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	14	-	5.3	7.0	7.97	6.7	7.2	7.5
EC (uS/cm)	14	-	1016	1605	2002	1470	1655.5	1787
Aluminium (µg/L)	14	20	20	20	20	20	20	20
Arsenic (µg/L)	14	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Iron (µg/L)	14	20	20	21	40	20	20	20
Manganese (µg/L)	14	5	775	2327.1	3990	1040	2235	3730
Sulphate (mg/L)	14	0.1	425	504	555	454.2	515	537

FE1								
Analyte	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	16	-	5.6	7.1	7.79	7.0	7.2	7.3
EC (uS/cm)	16	-	790	1542	2048	1074	1730.5	1767
Aluminium (µg/L)	14	20	20	20	20	20	20	20
Arsenic (µg/L)	14	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Iron (µg/L)	14	20	20	21	40	20	20	20
Manganese (µg/L)	14	5	30	706.8	2680	120	280	1256
Sulphate (mg/L)	14	0.1	199	405	527	215	501.5	517

RBSP01								
Analyte	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	59	-	5.9	7.8	9.08	7.5	7.9	8.2
EC (uS/cm)	36	-	32	1451	6702	150	377.5	2836
Aluminium (µg/L)	27	20	20	6149	92200	20	70	5104
Arsenic (µg/L)	13	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Iron (µg/L)	27	20	20	2646	49000	20	60	1660
Manganese (µg/L)	27	5	1	226.3	3450	5	11	123
Sulphate (mg/L)	27	0.1	8	656	2810	29.2	148	1176

Ground Water Quality

RBGW01	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	5	-	6.75	7.29	8.16	7.05	7.19	7.39
EC (uS/cm)	4	-	6590	7405	8200	7004	7415	7810
Aluminium (µg/L)	3	20	10	10	10	10	10	10
Arsenic (µg/L)	4	0.5	1	1	1	1	1	1
Iron (µg/L)	5	20	50	186	280	138	210	240
Manganese (µg/L)	5	5	66	77	102	67.6	73	81.2
Sulphate (mg/L)	5	0.1	1	6.6	17	1	2	13

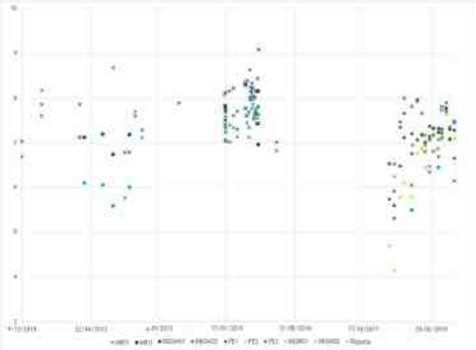
RBGW02	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	7	-	5.48	6.20	7.81	5.65	6.04	6.38
EC (uS/cm)	6	-	79.4	14577.6	21430	10096.2	18530	18800
Aluminium (µg/L)	5	20	10	38	140	10	10	44
Arsenic (µg/L)	5	0.5	0.5	1.8	4	0.5	1	3.2
Iron (µg/L)	7	20	60	4521.4286	9550	836	4300	7920
Manganese (µg/L)	7	5	8	313	561	36	429	541
Sulphate (mg/L)	7	0.1	1	388.18571	703	47.84	549	638.2

MB18	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	1	-	6.95	6.95	6.95	6.95	6.95	6.95
EC (uS/cm)	0	-	-	-	-	-	-	-
Aluminium (µg/L)	1	20	100	100	100	100	100	100
Arsenic (µg/L)	0	0.5	-	-	-	-	-	-
Iron (µg/L)	1	20	100	100	100	100	100	100
Manganese (µg/L)	1	5	1070	1070	1070	1070	1070	1070
Sulphate (mg/L)	1	0.1	2800	2800	2800	2800	2800	2800

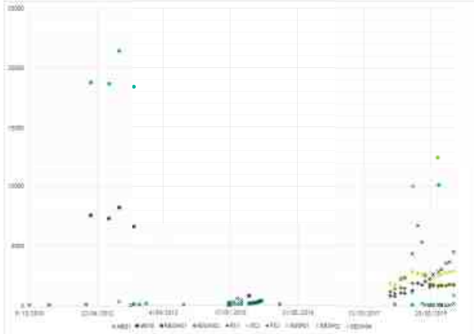
MB01	n	LoD	Min	Mean	Max	20%P	50%P	80%P
pH	3	-	6.88	7.16	7.63	6.91	6.96	7.36
EC (uS/cm)	2	-	9975.6	11247.75	12519.9	10484.46	11247.75	12011.04
Aluminium (µg/L)	3	20	10	16.666667	20	14	20	20
Arsenic (µg/L)	2	0.5	1	1.25	1.5	1.1	1.25	1.4
Iron (µg/L)	3	20	40	43.333333	50	40	40	46
Manganese (µg/L)	3	5	260	298.66667	366	264	270	327.6
Sulphate (mg/L)	3	0.1	91	179	249	133.4	197	228.2

Note that the following groundwater bores have no available water quality data and have not been included:

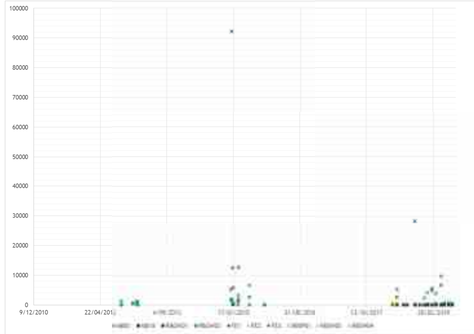
MB19	Water level data available
MB20	Water level data available
MB28	Water level data available
MB29	No data available
MB30	No data available
RN38292	No data available
RN38291	No data available



pH

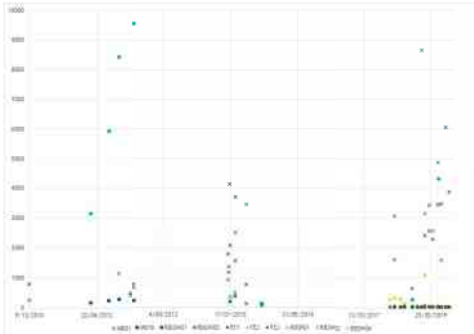


EC (µS/cm)

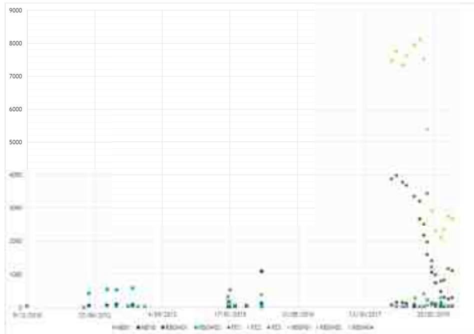


Aluminium (µg/L)

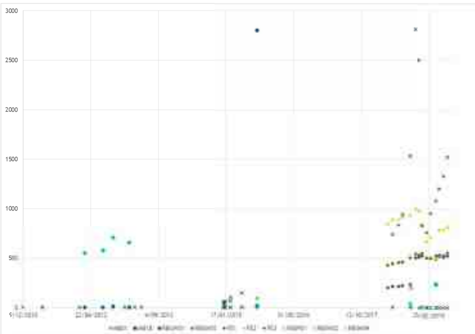
Arsenic (µg/L)



Iron (µg/L)



Manganese (µg/L)



Sulfate (mg/L)

Memorandum

Date	12 November 2019	Pages	11
Attention	Jim Barker		
Company	METServe		
Job No.	1547-02-E2		
Subject	Preliminary review of water quality data to derive trigger values suitable for the receiving waters for the Roper Bar Mine		

Dear Jim

Overview

Mining & Energy Technical Services Pty Ltd (METServe) have requested WRM Water and Environment (WRM) to undertake a preliminary review of available receiving waters water quality data at the Roper Bar Mine (RBM). The review is to derive suitable local trigger values for the RBM Environmental Management System (EMS) based on background values in the local waterways and relevant trigger values from the *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC & ARMCANZ, 2000).

The review has been undertaken using RBM surface water quality data collected at the following monitoring sites:

- three reference sites upstream of the mine on the following drainage lines:
  - Towns River at the monitoring points RBSW01 and RBSW02; and
  - A tributary of the Maganaryi River at monitoring point RBSW13.
- four receiving waters sites downstream of the mine on the following drainage lines:
  - Towns River at the monitoring points RBSW04, RBSW05 and RBSW14; and
  - Maganaryi River at monitoring point RBSW15.

The proposed local water quality trigger levels for RBM have been derived in accordance with ANZECC & ARMCANZ (2000) guidelines. These guidelines outline the requirements for deriving local water quality trigger levels.

Surface water site specific trigger values

To derive site-specific trigger values, ANZECC & ARMCANZ (2000) states the following:

> *For these Guidelines, data collected after two years of monthly sampling are regarded as sufficient to indicate ecosystem variability and can be used to derive trigger values.*

The guidelines state that a minimum of 24 monthly data points should be collected in a two-year period before they are used to derive site specific guideline values. Of the nine natural surface water sites, the most sampled site in close proximity to

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the mine (RBSW04) has a maximum total of 10 monthly samples in a two-year period. There is therefore not yet the recommended minimum number of data samples to derive site specific trigger values for the RBM receiving waters. This is because NRR has only recently acquired the RBM and has not been on site long enough to acquire the required number of samples.

In the absence of sufficient data, the ANZECC & ARMCANZ (2000) guidelines recommend the use of default trigger values. The adopted surface water quality indicators relevant to protecting declared beneficial uses including aquatic ecosystems are given in ANZECC & ARMCANZ (2000).

ANZECC & ARMCANZ (2000) Trigger Values

The ANZECC & ARMCANZ (2000) guideline values for physical and chemical stressors in lowland rivers for Tropical Australia are summarised in Table 1. The ANZECC & ARMCANZ (2000) guideline values for metals, metalloids and non-metallic inorganics for different ecosystem protection levels are summarised in Table 2. Table 1 and Table 2 also summarises the ANZECC & ARMCANZ (2000) guideline values for stock drinking water limits.

It is initially proposed to adopt the ANZECC & ARMCANZ (2000) default triggers for physical and chemical stressors and 95% protection for freshwater ecosystems for toxicants unless interim locally derived values or guidelines are considered appropriate based on the below analysis. This will allow RBM time to operate with an interim set of triggers until they collect a suitable amount of monitoring data to develop locally derived triggers.

Table 1 - Default trigger values for physical and chemical stressors (Tropical Australia, Lowland River) (ANZECC & ARMCANZ, 2000)

Parameter	Lowland River Trigger value	Stock Drinking Water Limits
pH	6 – 8	4 – 9
Electrical Conductivity (µS/cm)	250	5,970
Turbidity (NTU)	15	-
Chlorophyll (µg/L)	5	-
Total Phosphorous (µg/L)	10	-
Filterable Reactive Phosphorous (µg/L)	4	-
Total Nitrogen (µg/L)	300	-
Nitrogen Oxide (NOx) (µg/L)	10	-
Ammonium (µg/L)	10	-
Dissolved Oxygen (% saturation)	85 - 120	-

Table 2 - Specific toxicant default trigger values for ecosystem protection in freshwater as well as stock drinking water limits (ANZECC & ARMCANZ, 2000)

Toxicant	Level of aquatic ecosystem protection (% species)[a]				Stock Drinking Water Limits[b]
	99%	95%	90%	80%	
Metals & Metalloids (µg/L)					
Aluminium (pH filtered >6.5)	27	55	80	150	5,000
Arsenic (AS III)	1	24	94	360	500
Arsenic (AS V)	0.8	13	42	140	-
Boron	90	370	680	1,300	-
Cadmium	0.06	0.2	0.4	0.8	10
Chromium	0.01	1.0	6	40	1,000
Copper	1.0	1.4	1.8	2.5	1,000
Lead	1.0	3.4	5.6	9.4	100
Manganese	1,200	1,900	2,500	3,600	10,000
Mercury	0.06	0.6	1.9	5.4	
Nickel	8	11	13	17	1,000
Selenium (Total)	5	11	18	34	34
Silver	0.02	0.05	0.1	0.2	-
Zinc	2.4	8.0	15	31	20,000
Non-Metallic Inorganics (µg/L)					
Ammonia (Total)	320	900	1,430	2,300	-
Chlorine	0.4	3	6	13	-
Cyanide	4	7	11	18	-
Nitrate	17	700	3,400	17,000	-
Hydrogen sulfide	0.5	1.0	1.5	2.6	-
Sulfate[c]	-	-	-	-	1,000
Calcium	-	-	-	-	1,000
Magnesium	-	-	-	-	1,000[d]

[a] Applicable to filtered (dissolved) samples for metals and metalloids

[b] Applicable to total samples for metals and metalloids

[c] Australian Drinking Water Guideline (NHMRC, NRMMC 2011) value is 250 mg/l (aesthetic considerations - taste) and 500 mg/l (purgative effects)

[d] South African proposed upper limit for livestock drinking water (DWAF 1996)

Available data

Natural surface water quality data collected at RBM between December 2010 and August 2019 was provided by NRR for this review. The water quality parameters available for the three reference sites and three receiving waters sites which are relevant to ANZECC & ARMCANZ (2000) trigger levels investigated for this review are as follows:

- Dissolved and total metals –Aluminium (Al), Arsenic (As), Boron (B), Cadmium (Cd), Chromium (Cr), Copper (Cu), Manganese (Mn), Nickel (Ni), Lead (Pb), Selenium (Se), Silver (Ag), and Zinc (Zn);
- Turbidity;
- Electrical Conductivity (EC);

- pH;
- Ammonia;
- Calcium;
- Magnesium;
- Nitrate; and
- Sulphate.

A detailed review of the surface water quality at and in the vicinity of RBM was undertaken by WRM for NRR in a document entitled *Surface water and Groundwater Quality Assessment* (WRM, 2019).

RBSW14 was included in this review although elevated salt concentrations at RBSW14 suggests that salt concentrations in natural surface water are naturally elevated during baseflow conditions. This site is approximately 16.8 km northeast (downstream) of RBM and located within the Limmen National Park and upstream of the Limmen Bight coastal floodplains.

Table 3 and Table 4 show the summary of surface water quality statistics from WRM (2019) for the relevant natural surface water quality parameters investigated in the vicinity of RBM for the Towns River and the Magaranyi River respectively. Note that the blue shaded cells show values below the limit of detection (LOD) and orange shaded cells show values that exceed the ANZECC & ARMCANZ (2000) trigger values.

Due to the limited number of sample points for some parameters, both the 80th percentile and maximum values were considered when deriving the interim local trigger levels, where appropriate.

Table 3 – Towns River Water quality data statistics (2010 to 2019)

Analyte	LOD	ANZECC & ARMCANZ (2000) Trigger Value/Range	Upstream sites				Downstream sites					
			RBSW01		RBSW02		RBSW04		RBSW05		RBSW14	
			80%ile	Max	80%ile	Max	80%ile	Max	80%ile	Max	80%ile	Max
Field parameters												
pH (upper)	-	>8[a] / >9[b]	7.8	8.15	7.8	8.63	7.8	8.68	7.6	8	7.9	8.3
pH (lower)[d]		<6 [a] / <4 [b]	7.0	6.8	7.0	6.0	7.1	5.7	6.7	5.4	7.3	6.5
EC (µS/cm)	-	250[a] / 5,970[b]	70.8	121	211	1,156	188	853	90	230	1,021	18,677
DO (%)	-	85-120[a]	97	108	94	121	93	118	85	96	91	120
Turbidity (NTU)	-	15[a]	109	361	102	800	194	800	81	216	92	1,315
Metals and metalloids												
Aluminium (µg/L)	20	55[a]	2,918	6,540	2,546	28,400	4,400	9,600	932	1,260	732	1,060
Arsenic (AS V) (µg/L)	0.5	13[a]	1	1	1	1	1	2.5	1	1	1	2
Boron (µg/L)	20	370[a]	50	50	80	520	80	100	56	80	80	1,220
Cadmium (µg/L)	0.2	0.2[a]	0.10	0.20	0.20	0.20	0.20	0.20	0.10	0.10	0.20	0.40
Chromium (µg/L)	5	1[a]	1	5	5	20	5	5	1	1	5	5
Copper (µg/L)	10	1.4[a]	2	10	10	10	10	10	1	1	9.8	10
Manganese (µg/L)	5	1,900[a]	11.6	21.0	49	205	24.4	390	10.2	312	12	206
Nickel (µg/L)	2	11[a]	1	2	2	4	2	2	1	1	2.0	2
Lead (µg/L)	1	3.4[a]	1	1	1	2	1	2	1	1	1	1
Selenium (µg/L) (total)	1	11[a]	10	10	2	10	10	10	10	10	10	10
Silver (µg/L)	10	0.05[a]	6.4	10	10	10	10	10	1	1	10	10
Zinc (µg/L)	10	8[a]	6.6	10	10	10	10	10	6.6	30	10	26
Cations, Anions and Nutrients												
Calcium (mg/L)	0.1	1,000[b]	2	2	2	10	2.1	6	1.2	9	54.56	172
Magnesium (mg/L)	0.1	1,000[b]	2	4	3	13.8	3.9	6.7	2.2	10	62.14	406
Sulphate (mg/L)	0.1	250[c]/500[c]/1,000[b]	3	5	3	37.4	3.6	8.8	3.8	6	138	756
Ammonia as N NH3_N (mg/L)	0.005	0.74	0.06	0.11	0.225	1.65	0.165	0.305	0.024	0.11	0.02	0.17
Nitrate NO3 (mg/L)	0.02	0.7[a]	0.02	0.02	0.16	2.5	0.05	0.16	0.038	0.14	0.02	0.09

[a] 95% freshwater ecosystem protection (applicable to filtered (dissolved) samples for metals and metalloids)

[b] stock watering values (applicable to total samples for metals and metalloids)

[c] Australian Drinking Water Guideline (NHMRC, NRMMC 2011) value is 250 mg/l (aesthetic considerations - taste) and 500 mg/l (purgative effects)

[d] Inverse is applied to pH (lower) ie. 80th percentile column corresponds to the 20th percentile value and Maximum column corresponds to minimum value

Table 4 – Magaranyi River Water quality data statistics (2010 to 2019)

Analyte	LOD	ANZECC & ARMCANZ (2000) Trigger Value/ Range	Upstream RBSW13		Downstream RBSW15	
			80%ile	Max	80%ile	Max
Field parameters						
pH (upper)	-	>8[a] / >9[b]	7.6	7.84	7.8	8.51
pH (lower)		<6 [a] / <4 [b]	6.9	5.3	7.1	6.1
EC (µS/cm)	-	250[a] / 5,970[b]	103	314	42	70
DO (%)	-	85-120[a]	97	115	100	110
Turbidity (NTU)	-	15[a]	55	245	95	673
Metals and Metalloids						
Aluminium (µg/L)	20	55[a]	1,388	1,580	952	1,870
Arsenic (AS V) (µg/L)	0.5	13[a]	1	1	1	10
Boron (µg/L)	20	370[a]	48	60	50	100
Cadmium (µg/L)	0.2	0.2[a]	0.20	0.20	0.20	5
Chromium (µg/L)	5	1[a]	5	5	2.6	10
Copper (µg/L)	10	1.4[a]	10	10	4.6	10
Manganese (µg/L)	5	1,900[a]	14.4	85	5	20
Nickel (µg/L)	2	11[a]	2	2	2	10
Lead (µg/L)	1	3.4[a]	1	1	1	10
Selenium (µg/L) (total)	1	11[a]	1	10	10	10
Silver (µg/L)	10	0.05[a]	10	10	4.6	10
Zinc (µg/L)	10	8[a]	10	16	10	19
Cations, Anions and Nutrients						
Calcium (mg/L)	0.1	1,000[b]	2	2.5	1	3
Magnesium (mg/L)	0.1	1,000[b]	2	2.8	2	4
Sulphate (mg/L)	0.1	250[c]/500[c]/1,000[b]	1	1.3	1	11
Ammonia as N NH_3_N (mg/L)	0.005	0.74[d]	0.034	0.085	0.022	0.06
Nitrate NO_3 (mg/L)	0.02	0.7[a]	0.032	0.17	0.03	0.4

[a] 95% freshwater ecosystem protection (applicable to filtered (dissolved) samples for metals and metalloids)

[b] stock watering values (applicable to total samples for metals and metalloids)

[c] Australian Drinking Water Guideline (NHMRC, NRMMC 2011) value is 250 mg/l (aesthetic considerations - taste) and 500 mg/l (purgative effects)

Memorandum

Comparison of local water quality data with ANZECC & ARMCANZ (2000) trigger levels.

pH

Table 3 and Table 4 show the 20th to 80th percentile pH values derived from the RBM natural surface water monitoring sites range from 6.7 to 7.9. Table 3 and Table 4 also show that the minimum to maximum values range from 5.3 to 8.7. The ANZECC & ARMCANZ (2000) default trigger value range for pH is 6 to 8.

The water quality results for pH indicate that adoption of an interim 80th percentile locally derived range of 5.5 to 8.5 would increase the receiving water trigger range for pH, compared to using the ANZECC & ARMCANZ (2000) default trigger range of 6 to 8.

Electrical Conductivity (EC)

Table 3 and Table 4 show the 80th percentile electrical conductivity derived from the RBM natural surface water monitoring sites range from 71 to 201 µS/cm for upstream sites and 42 to 1,021 µS/cm for downstream sites. Table 3 and Table 4 also show that the maximum values range from 70 to 18,677 µS/cm. The ANZECC & ARMCANZ (2000) default trigger value for turbidity is 250 µS/cm.

The water quality results for electrical conductivity indicate that adoption of an interim 80th percentile locally derived level of 1,021 µS/cm would increase the receiving water trigger level for electrical conductivity, compared to using the ANZECC & ARMCANZ (2000) default trigger value of 250 µS/cm.

Turbidity

Table 3 and Table 4 show the 80th percentile turbidity concentration derived from the RBM natural surface water monitoring sites range from 55 to 109 NTU for upstream sites and 81 to 194 NTU for downstream sites. Table 3 and Table 4 also shows that the maximum values range from 216 to 1,315 NTU. The ANZECC & ARMCANZ (2000) default trigger value for turbidity is 15 NTU.

The water quality results for turbidity indicate that adoption of an interim 80th percentile locally derived level of 194 NTU would increase the receiving water trigger level for turbidity, compared to using the ANZECC & ARMCANZ (2000) default trigger value of 15 NTU.

Sulphate

ANZECC & ARMCANZ (2000) does not recommend a sulphate concentration for freshwater aquatic ecosystems.

In the absence of this, it is recommended that the Australian Drinking Water Guidelines (NHMRC, NRMMC 2011) drinking water guideline of 500 mg/L be adopted as the interim Sulphate trigger, which is the receiving waters trigger value adopted for mines in Queensland.

It is noted that a maximum sulphate concentration of 756 mg/L has been measured at RBSW14.

Metals

Table 5 shows the 80th percentile values for aluminium measured both upstream and downstream of the RBM exceed the ANZECC & ARMCANZ (2000) 95% freshwater ecosystem protection trigger levels. Table 5 also shows the maximum values for aluminium, boron, cadmium, chromium and zinc exceed the ANZECC & ARMCANZ (2000) 95% freshwater ecosystem protection trigger levels. The 80th percentile and maximum concentration values for arsenic, copper, manganese, nickel, lead, selenium and silver are either below the limit of detection (LOD) or below the ANZECC & ARMCANZ (2000) 95% protection values.

The available values indicate that five metals shown in Table 5 have recorded higher concentrations in the receiving waters than the values given in ANZECC & ARMCANZ (2000) for 95% freshwater ecosystem protection.

Table 5 indicates that the trigger level for the above five metals could potentially be based on locally derived levels. Therefore, it is recommended that the current suite of metals continue to be monitored until there is a suitable number of samples.

Table 5 - Derived local trigger levels for metals compared with ANZECC & ARMCANZ (2000)

Parameter	ANZECC & ARMCANZ (2000) trigger level (µg/L)	Recorded 80th percentile total (µg/L)	Recorded Maximum value (µg/L)	Site(s) that recorded exceedances
Aluminium	55	932 - 4400	1050 - 28,400	All sites
Boron	370	48 - 80	520 - 1,220	RBSW02 RBSW14
Cadmium	0.2	< LOD (0.2)	< LOD - 5	RBSW14 RBSW15
Chromium	1	< LOD (10)	< LOD - 20	RBSW02 RBSW15
Zinc	8	< LOD (10)	16 - 30	RBSW05 RBSW14 RBSW13 RBSW15

Recommendations

Based on currently available information, the following interim receiving water trigger levels are recommended to be adopted for the RBM during a mine water release event:

- pH - locally derived range of 5.5 to 8.5.
- electrical conductivity - locally derived value of 1,021 µS/cm.
- turbidity - locally derived value of 194 NTU;
- sulphate - NHMRC, NRMMC (2011) drinking water guideline value of 500 mg/l; and
- aluminium, boron, cadmium, chromium, and zinc – locally derived lowest maximum values recorded in the receiving waters monitoring locations listed in Table 5. If the lowest value is exceeded during a release event, it is possible that similar exceedances occur in upstream monitoring locations as

well and this should be confirmed (Ongoing monthly monitoring of the receiving waters is required to confirm these values).

Adopting the interim receiving water quality trigger levels proposed below for the RBM, which are based on local measurements and ANZECC & ARMCANZ (2000) guideline values, will help limit the occurrence of non-compliances due to naturally occurring (non-mine related) events.

It is recommended that the ANZECC & ARMCANZ (2000) values for all other parameters are adopted, until local or regional data is available to derive more site-specific trigger levels. A comparison of the ANZECC & ARMCANZ (2000) trigger levels for receiving waters and those recommended from either locally derived values or guideline values is shown in Table 6 and Table 7.

A review of the RBM groundwater quality data in WRM (2019) found that the water quality in a number of regional groundwater bores exceeded the ANZECC & ARMCANZ (2000) stock water guidelines. Hence, it is recommended that appropriate management measures are implemented to prevent livestock access to water storages that contain groundwater that exceeds the ANZECC & ARMCANZ (2000) stock water trigger levels.

It is also recommended that once the required minimum number of samples are collected, the required suite of parameters to be monitored in mine water storages and the receiving environment is reviewed and refined. The review of RBM water quality data collected to date for mine water dams in WRM (2019) indicated that a number of parameters are well below the ANZECC & ARMCANZ (2000) trigger values and may not have to be monitored.

Table 6 -Trigger limits for physical and chemical stressors in receiving waters

Parameter	(ANZECC & ARMCANZ 2000) lowland River Trigger limit	(ANZECC & ARMCANZ 2000) stock Drinking water lmit	Recommended locally derived interim limit
pH	6 to 8	4 to 9	5.5 to 8.5
Electrical Conductivity (µS/cm)	250	5,970	1,021
Turbidity (NTU)	15	-	194
Chlorophyll (µg/L)	5	-	-
Total Phosphorous (µg/L)	10	-	-
Filterable Reactive Phosphorous (µg/L)	4	-	-
Total Nitrogen (µg/L)	300	-	-
Nitrogen Oxide (NOx) (µg/L)	10	-	-
Ammonium (µg/L)	10	-	-
Dissolved Oxygen (% saturation)	85 to 120	-	-

Table 7 -Trigger values for toxicants in receiving waters

Parameter	ANZECC & ARMCANZ (2000) 95% protection	NHMRC, NRMMC (2011) guideline levels	Recommended locally derived levels	Note
Al (µg/L)	55		1,050	Needs confirmation after collecting the required minimum number of reference site samples
As (µg/L)	13			
B (µg/L)	370		520	Needs confirmation after collecting the required minimum number of reference site samples
Cd(µg/L)	0.2		<0.2	Needs confirmation after collecting the required minimum number of reference site samples
Cr (µg/L)	1		<10	Needs confirmation after collecting the required minimum number of reference site samples
Cu (µg/L)	2			
Fe (µg/L)	300			
Pb (µg/L)	4			
Mn (µg/L)	1,900			
Hg (µg/L)	0.2			
Ni (µg/L)	11			
Se (µg/L)	10			
Ag (µg/L)	1			
Zn (µg/L)	8		16	Needs confirmation after collecting the required minimum number of reference site samples
Ammonia (µg/L)	900			
Nitrate (µg/L)	700			
Sulphate (mg/L)	-	500		As per drinking water guidelines (NHMRC, NRMMC 2011)

I trust this advice is of assistance. Please don't hesitate to contact me if you would like to discuss the results.

For and on behalf of
WRM Water & Environment Pty Ltd

Julian Orth
Principal Engineer

References:

ANZECC & ARMCANZ (2000)	'*ANZECC (Australian and New Zealand Environment and Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand)* 2000', Australian Guidelines for Water Quality Monitoring and Reporting. National Water Quality Management Strategy Paper No. 7, ANZECC and ARMCANZ, Canberra.
DWAF (1996)	'*South African water quality guidelines*', 2nd edn, vol 5: Agricultural use: Livestock watering. CSIR Environmental Services, Pretoria.
NHMRC, NRMMC (2011)	'*Australian Drinking Water Guidelines*' Paper 6 National Water Quality Management Strategy. Version 3.5. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.
WRM (2019)	'*Surface water and Groundwater Quality Assessment*', prepared by WRM for NRR, 6 September 2019.

Appendix F: Standard Operating Procedure: Data Storage and Processing

Waste Rock Data Processing Procedure

For Management of Acid Metalliferous Drainage

Roper Bar Iron Ore Mine

NATHAN RIVER PROJECT

Date:	November 2019
Report No.:	NRR19 - 03
Author:	Gavin Otto, Geology Manager
Revision:	Version 1

Table of Contents

Purpose

This procedure outlines the methods for processing and spatial visualisation of data collected from waste rock samples for the management of potential acid forming (PAF) waste material mined at the Roper Bar Iron Ore Mine.

Scope

This procedure is applicable to all geochemical analytical data collected from waste rock sampling.

This procedure forms a part of the Nathan River Project Acid Metalliferous Drainage Management Plan.

Responsibility

The Geology Department is responsible for the identification of PAF material and communicating this information to the Mining Department. The Mining Department is responsible for the removal and storage of PAF. The Environmental Department is responsible for the monitoring of surface and ground water to identify whether any acid mine drainage is occurring.

The Manager/Supervisor shall ensure that:

- Waste rock is adequately characterised through sampling and analysis;
- Any identified PAF is communicated in a timely fashion to the Mining Department;
- Adequate resources are available to process the data returned by waste rock sampling;
- Adequate training is given to all staff using this procedure.

The OHS Officer:

- Will ensure that all related sampling procedures are being adhered to by all workers;
- Will ensure that all workers involved in sampling procedures have been adequately trained in conducting hazard analyses and managing risk associated with waste rock sampling;
- Will respond immediately to all identified substandard conditions, hazards, defects, or noncompliance to the sampling procedures.

The Worker:

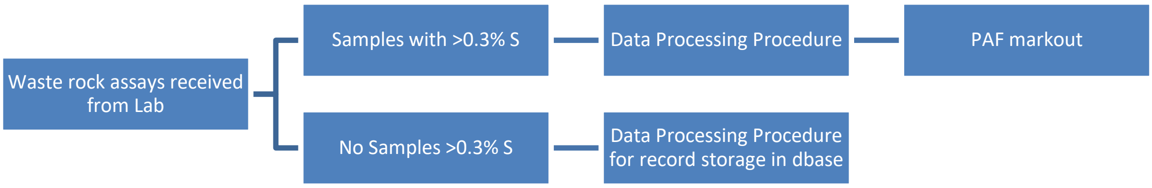
- Will participate in any team identified as needed to develop procedures for protection as required;
- Will report immediately to the supervisor any identified defects, hazards, or substandard conditions;
- Will abide by all waste rock data processing procedures when processing the waste rock sample data and ensure that the data is accurate and readily available.

Definitions

- NRR – NRR Mining Pty Ltd
- CSV – comma delimited file, a file format for transferring data
- XRF – X-Ray Fluorescence, also refers to a portable XRF device
- PAF – Potentially Acid Forming, waste rock with >= 0.3% Sulphur content

Introduction

Waste rock assays must be checked by Senior Mine Geologist or delegate when results are received by email from the laboratory. If results contain samples with > 0.3% S, then this procedure must be completed in a timely manner to ensure that indicated PAF material is spatially identified. A PAF markout (if required) must be designed, surveyed on the ground and marked out prior to any mining on the shot. PAF markouts are to be designed for 2 or more adjacent PAF samples.



Procedure

1. Collected sample data and the sample submission data (Dispatch) for the laboratory is entered into the Excel spreadsheet **Waste Rock Data.xlsx**. Geological data is entered into this same spreadsheet, under the Geology tab. The Dispatch Number will be DATE_BLAST (eg 140523_FE_000_106)

2. The Senior Geologist or delegate ensures that the data is correct and valid before copying the data from **Waste Rock Data.xlsx** into the database **Waste_rock_NRR.accdb**. Sample data is copied into Sampling table, and Geology is copied into Geology table. Only samples with a Dispatch number are entered at this time.

3. Assay results are to be copied to **\\MINING\Waste Rock Sampling\Assay Results** as they are received from the laboratory. The original assay result files are to be retained and archived for audit purposes. A working copy of the assay results file marked as **_processed** can be edited for processing and formatting for database entry.

4. The sample assays are to be checked to ensure there are no errors in the sample numbers. Any inserted standard results are to be checked that returned results fall within expected values.

5. Edit the file and delete any repeat or laboratory standards as shown in Figure 1.

6. Copy the trimmed results into **\\Assay Results processing.xlsx**, Lab Assay results sheet. In the top left copy and paste the Laboratory Job number and Sample Dispatch from the working assay result file (Figure 2).

7. The Lab results for import tab of **\\Assay Results processing.xlsx** will now populate with the reformatted data. Copy this data into the access database **Waste_rock_NRR.accdb**, Assay_Results table. Close the excel sheet without saving and move the lab csv file into the Processed and Imported folder.

8. For portable XRF data the process is similar, copy the XRF results csv and ndt files into **\\XRF Results**. The ndt is moved into XRF ndt Files folder. XRF samples are given a unique Sample ID, for this use DATE-##, eg 20140524-05.

	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.001	0.01
Sample Number	%	%	%	%	%	%	%	%	%	%	%
EEWR0204	38.38	37.34	2.19	0.67	0.09	<0.01	0.16	0.09	0.004	0.009	4.8
EEWR0205	41.73	32.7	2.36	0.8	0.1	<0.01	0.15	0.1	0.004	0.002	4.07
EEWR0206	46.59	27.01	2.08	0.46	0.08	<0.01	0.11	0.08	0.004	0.004	3.74
EEWR0207	50.17	22.45	1.9	0.31	0.07	<0.01	0.17	0.06	0.004	0.004	3.07
EEWR0208	50.82	20.94	2.47	0.33	0.09	<0.01	0.21	0.08	0.004	0.002	3.21
EEWR0209	50.24	19.8	3.51	0.34	0.12	<0.01	0.25	0.11	0.007	0.003	3.75
EEWR0210	56.57	14.69	1.69	0.23	0.05	<0.01	0.15	0.06	0.003	0.003	2.15
EEWR0211	23.41	53.59	5.22	0.67	0.25	<0.01	0.28	0.28	0.008	0.006	5.78
EEWR0212	23.36	53.66	5.7	0.72	0.25	<0.01	0.38	0.3	0.006	0.023	5.85
EEWR0213	20.31	59.48	4.68	0.72	0.22	<0.01	0.39	0.25	0.006	0.024	5.22
EEWR0214	22.53	55.4	5.03	0.66	0.24	<0.01	0.41	0.26	0.007	0.032	5.83
EEWR0215	18.19	61.98	5.48	0.4	0.26	<0.01	0.49	0.29	0.007	0.046	5.26
EEWR0216	15.02	64.63	6.85	0.33	0.32	<0.01	0.57	0.4	0.007	0.034	5.42
EEWR0217	15.56	62	5.84	0.32	0.27	<0.01	1.33	0.35	0.006	0.102	7.72
EEWR0218	16.7	62.95	6.13	0.24	0.28	<0.01	0.62	0.38	0.007	0.068	5.37
EEWR0219	12.09	66.37	9.2	0.19	0.41	<0.01	0.59	1.07	0.012	0.039	5.25
EEWR0219 Rpt	12.03	66.43	9.22	0.19	0.41	<0.01	0.59	1.07	0.012	0.036	5.33
EEWR0220	12.44	65.36	9.52	0.13	0.42	<0.01	0.68	1.02	0.011	0.025	5.32
EEWR0221	10.98	66.28	10.11	0.17	0.44	<0.01	0.7	1.18	0.012	0.061	5.46
EEWR0222	10.71	67.18	10.01	0.13	0.45	<0.01	0.66	1.17	0.012	0.033	5.28
EEWR0223	16.47	63.3	6.62	0.26	0.3	<0.01	0.46	0.44	0.006	0.026	4.9
EEWR0224	24.76	52.73	4.98	0.64	0.22	<0.01	0.46	0.25	0.006	0.008	5.52
EEWR0225	26.69	51.27	4.01	0.62	0.17	<0.01	0.35	0.2	0.006	0.011	5.54
EEWR0226	22.91	56.66	4.37	0.44	0.2	<0.01	0.35	0.25	0.006	0.007	4.87
EEWR0227	54.37	16.66	1.81	0.16	0.06	<0.01	0.14	0.07	0.006	0.014	3.25
EEWR0228	44.75	27.61	3.04	0.28	0.12	<0.01	0.15	0.14	0.012	0.008	4.51
EEWR0228 Rpt	44.67	27.68	3.05	0.28	0.12	<0.01	0.16	0.14	0.011	0.009	4.54
Sarm 12_1_wd000	66.58	0.33	0.79	0.22	0.73	1.09	2.82	0.01	0.048	0.066	
LOI std 1_2_wd000814											1.26
NCS DC 14006a_3_	43.77	3.99	0.62	0.3	0.02	3.38	3.84	0.21	0.034	1.463	
LOI std 2_4_wd000814											5.58
OREAS 40_5_wd0C	66.6	4.64	0.13	0.01	0.04	<0.01	0.02	0.02	0.004	0.006	
LOI std 3_6_wd000814											10.21
BVAX02_7_wd000814											-1.67

Figure 1: Assay result table with highlighted laboratory repeats and standards

PO Number: wd001022

Dispatch number: FEWR140629_01

Sample Number	Fe	SIO2	AL2O3	MNO	TIO2	CAO	MGO	K2O	P	S	LOI
FEWR1196	5.15	65.23	15.53	0.08	0.7	0.02	1.48	4.07	0.013	0.033	4.77
FEWR1197	4.75	65.23	16.1	0.06	0.76	0.03	1.48	4.22	0.015	0.054	5.09
FEWR1198	5.06	65.73	15.65	0.08	0.71	0.02	1.48	4.09	0.015	0.031	4.9
FEWR1199	5.07	66.04	15.38	0.09	0.7	0.02	1.47	4.1	0.015	0.04	4.87
FEWR1200	3.7	66.68	14.6	0.1	0.66	0.03	1.4	3.89	0.015	0.036	4.56
FEWR1201	5.43	65.03	15.57	0.15	0.7	0.05	1.5	4.1	0.015	0.047	4.99
FEWR1202	4.29	66.67	16.04	0.09	0.74	0.02	1.46	4.02	0.016	0.011	4.68
FEWR1203	4.52	67.17	15.29	0.07	0.71	0.03	1.49	3.85	0.012	0.01	4.56
FEWR1204	4.1	69.43	14.27	0.06	0.65	0.02	1.5	3.81	0.013	0.01	4.2
FEWR1205	4.53	68.79	14.88	0.1	0.68	0.02	1.42	3.87	0.015	0.01	4.27
FEWR1206	6.21	72.8	9.86	0.23	0.43	0.02	1.36	3.21	0.013	0.011	3.22
FEWR1207	4.83	67.22	15.07	0.08	0.68	0.03	1.62	3.85	0.013	0.009	4.84
FEWR1208	4.7	63.14	17.25	0.08	0.77	0.03	1.72	4.19	0.016	0.01	5.48
FEWR1209	3.85	67.45	16.18	0.05	0.72	0.02	1.37	4.24	0.015	0.008	4.53
FEWR1210	4.74	64.99	16.79	0.07	0.74	<0.01	1.44	4.18	0.018	0.009	4.91
FEWR1211	4.12	62.62	15.78	0.06	0.7	0.03	3.73	4.02	0.014	0.009	7.1
FEWR1212	4.75	66.24	16.06	0.13	0.7	0.03	1.22	3.72	0.014	0.041	5.28
FEWR1213	9.62	63.74	12.16	0.01	0.51	0.02	0.82	2.19	0.014	0.079	5.77
FEWR1214	10.41	60.62	12.34	0.73	0.49	0.05	1.17	2.34	0.018	0.128	7.11
FEWR1215	8.18	63.71	13.46	0.44	0.51	0.04	1.13	2.62	0.016	0.062	6.14
FEWR1216	11.37	59.48	12.05	0.93	0.49	0.05	1.11	2.31	0.015	0.068	7.27
FEWR1217	7.74	62.16	15.62	0.54	0.66	<0.01	1.01	3.13	0.014	0.033	5.71
FEWR1218	4	66.48	16.56	0.07	0.72	0.02	1.2	3.81	0.016	0.064	5.35

Figure 2: Trimmed assay results in \\Assay _Results_processing.xlsx worksheet

9. Open the XRF results csv, delete any standards and copy the XRF results data into the **\\XRF Assay results.xlsx**, XRF Assay results sheet. Column J is where the sample numbers need to be entered as shown in Figure 3. Type in the file name into cell B1.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	File name:	20140524_FE_000_103					Fill this column in with sample number												
2																			
3	Reading No	Time	Type	Duration	Units	Sequence Res		EScale	Shape Tim	SAMPLE	LOCATION	INSPECTO	MISC	NOTE	User Login	Flags	MgO	MgO Error	Al2O3
4	6	24/05/2014 12:10	Mining	44	%	Final				20140524-01	fe_000_10				user	ModCF WI	0.944	0	12.114
5	7	24/05/2014 12:13	Mining	44	%	Final				20140524-02	fe_000_10				user	ModCF WI	2.058	0	7.92
6	8	24/05/2014 12:16	Mining	44	%	Final				20140524-03	fe_000_10				user	ModCF WI	1.36	0	6.836
7	9	24/05/2014 12:18	Mining	44	%	Final				20140524-04	fe_000_10				user	ModCF WI	1.543	0	11.494
8	10	24/05/2014 12:19	Mining	44	%	Final				20140524-05	fe_000_10				user	ModCF WI	3.789	0	16.517
9	11	24/05/2014 12:22	Mining	44	%	Final				20140524-06	fe_000_10				user	ModCF WI	1.728	0	8.636
10	12	24/05/2014 12:24	Mining	44	%	Final				20140524-07	fe_000_10				user	ModCF WI	1.461	0	12.662
11	13	24/05/2014 12:26	Mining	44	%	Final				20140524-08	fe_000_10				user	ModCF WI	3.696	0	16.667
12	14	24/05/2014 12:31	Mining	44	%	Final				20140524-09	fe_000_10				user	ModCF WI	2.243	0	8.77
13	15	24/05/2014 12:36	Mining	44	%	Final				20140524-10	fe_000_10				user	ModCF WI	0	0	7.818
14	16	24/05/2014 12:40	Mining	44	%	Final				20140524-11	fe_000_10				user	ModCF WI	3.296	0	7.479
15	17	24/05/2014 12:42	Mining	44	%	Final				20140524-12	fe_000_10				user	ModCF WI	1.323	0	6.473

Figure 3: \\XRF_Assay results.xlsx with highlighted Sample Number field

10. The XRF results for import sheet will now populate with data, copy this data into the access database **Waste_rock_NRR.accdb**, Assay_Results table. Close the excel sheet without saving and move the XRF csv file into the Processed and Imported folder.

11. The Waste rock database has a number of queries; Blastholes and Grab Samples are for reviewing data. The Export queries reformat the data to use with Surpac. The Crest, Toe and Point RL filters display the data for a single 2.5m bench, e.g. the 5 - 2.5 RL bench will include blasthole samples from 10 to 0 RL as well as grab samples from 6 RL. Filter the data for each requested RL.

12. Copy the selected filtered data into **\\Export Processing.xlsx**, cell A1 and enter the required RL in the yellow box (Figure 4). Columns K-Q arrange the data and which is used to populate Column T as the data format required for Surpac string files. Select column T and copy the data fields.

	A	B	C	D	E	F	G	I	K	L	M	N	O	P	Q	T
1	Northing	Easting	Crest_RL	Toe_RL	Point_RL	S_%			export	24-May-14		SSI_STYLES:styles.ssi				export,24-May-14,,SSI_STYLES:styles.ssi
2	8325414	508884	10	0		0.11			0	0	0	0	0	0	0	0,0,0,0,0,0,0
3	8325410	508832	10	0		0.21	Bench crest RL:	5	16	8325414	508884	5	0.11			16,8325414,508884,5,0.11
4	8325406	508821	10	0		0.14			0	0	0	0				0,0,0,0,
5	8325402	508810	10	0		0.15			16	8325410	508832	5	0.211			16,8325410,508832,5,0.211
6	8325390	508808	10	0		0.10			0	0	0	0				0,0,0,0,
7	8325394	508819	10	0		0.06			16	8325406	508821	5	0.144			16,8325406,508821,5,0.144
8	8325415	508812	10	0		0.13			0	0	0	0				0,0,0,0,
9	8325427	508846	10	0		0.08			16	8325402	508810	5	0.154			16,8325402,508810,5,0.154
10	8325431	508857	10	0		0.14			0	0	0	0				0,0,0,0,
11	8325436	508849	10	0		0.10			16	8325390	508808	5	0.096			16,8325390,508808,5,0.096
12	8325434	508842	10	0		0.09			0	0	0	0				0,0,0,0,
13	8325431	508835	10	0		0.19			16	8325394	508819	5	0.059			16,8325394,508819,5,0.059
14	8325429	508829	10	0		0.11			0	0	0	0				0,0,0,0,
15	8325427	508822	10	0		0.14			16	8325415	508812	5	0.134			16,8325415,508812,5,0.134
16	8325424	508816	10	0		0.13			0	0	0	0				0,0,0,0,
17	8325418	508799	10	0		0.11			16	8325427	508846	5	0.077			16,8325427,508846,5,0.077
18	8325398	508830	10	0		0.03			0	0	0	0				0,0,0,0,
19	8325402	508842	10	0		0.03			16	8325431	508857	5	0.142			16,8325431,508857,5,0.142
20	8325406	508853	10	0		0.06			0	0	0	0				0,0,0,0,
21	8325410	508864	10	0		0.03			16	8325436	508849	5	0.099			16,8325436,508849,5,0.099
22	8325414	508876	10	0		0.03			0	0	0	0				0,0,0,0,
23	8325426	508878	10	0		0.69			16	8325434	508842	5	0.089			16,8325434,508842,5,0.089
24	8325422	508866	10	0		0.14			0	0	0	0				0,0,0,0,
25	8325418	508855	10	0		0.10			16	8325431	508835	5	0.194			16,8325431,508835,5,0.194
26	8325435	508868	10	0		0.15			0	0	0	0				0,0,0,0,
27	8325439	508855	10	0		0.06			16	8325429	508829	5	0.112			16,8325429,508829,5,0.112
28	8325411	508862	10	0		0.69			0	0	0	0				0,0,0,0,
29	8325443	508868	10	0		0.19			16	8325427	508822	5	0.135			16,8325427,508822,5,0.135
30	8325446	508875	10	0		0.16			0	0	0	0				0,0,0,0,
31	8325448	508882	10	0		0.09			16	8325424	508816	5	0.133			16,8325424,508816,5,0.133
32	8325439	508880	10	0		0.03			0	0	0	0				0,0,0,0,
33	8325378	509045	10	0		0.08			16	8325418	508799	5	0.106			16,8325418,508799,5,0.106
34	8325374	509034	10	0		0.16			0	0	0	0				0,0,0,0,
35	8325371	509024	10	0		0.08			16	8325398	508830	5	0.033			16,8325398,508830,5,0.033
36	8325367	509014	10	0		0.07			0	0	0	0				0,0,0,0,
37	8325364	509004	10	0		0.10			16	8325402	508842	5	0.028			16,8325402,508842,5,0.028

Figure 4: \\Export Processing.xlsx RL selection

13. Surpac string files (as *.csv files) for the PAF assay results for individual bench RL's are stored in **\\Strings**. Open the csv string file one for your requested RL (or copy and rename an existing one if it doesn't exist). Select all data in the file and delete all the data in the string file. Paste the new data copied from Step 12, ensuring all blank entries at the end of the data are removed. Save and close the csv string file. Rename the string file to *.str. Close **\\Export Processing.xlsx** without saving.

14. Open Surpac and load the new RL string created in Step 13. Load the block model section for the corresponding RL by dragging it from the Surpac Navigator window while holding the Ctrl key before releasing the mouse button. This action will combine the two string files into a single layer.

15. Go to Edit > Layer > Clean, function Duplicate Point to remove duplicate points with a minimum and maximum trap distance of 0 (Figure 5). This will remove any duplicate points (but may take a few minutes). When complete save the block model section for the RL.

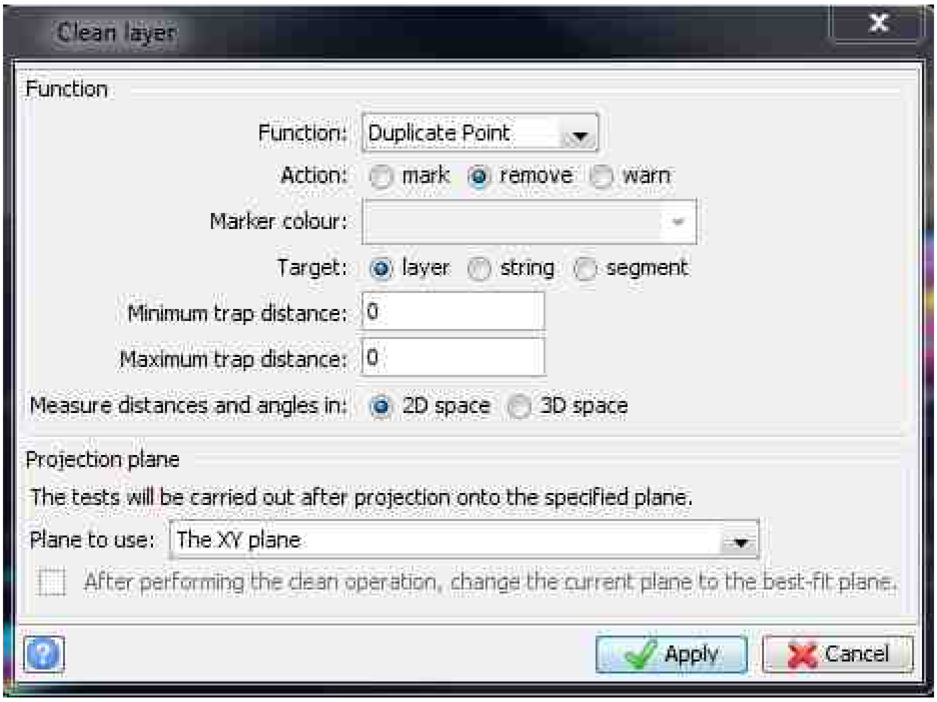


Figure 5: Surpac function Remove Duplicates

16. Repeat Steps 11 to 15 for all new waste rock data to be imported into Surpac.

Environmental Implications

No environmental implications.

Health and Safety Implications

No health and safety implications.

Hazard & Potential Incident Checklist

Nil.

Legal Requirements

Nil.

Records

No records

Related Documents

NRR_Waste Rock Sampling Procedure_V2

Record of Revisions

Ver No.	Date	Section	Description of Revision	Prepared/Revised by
1	November 2019		Version 1	Gavin Otto

Document Control

This procedure is a controlled document.

This procedure will be reviewed and updated as required.