# Sulphur Springs Zinc-Copper Project

# Conceptual Mine Closure Plan

M45/494, M45/653, M45/1001, L45/166, L45/170, L45/173, L45/179, L45/189.

**January 2020**

**Tenement holder:** Venturex Sulphur Springs Pty Ltd

# Conceptual Mine Closure Plan

## Distribution

| Company | Copies | Contact Name |
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| Venturex Resources Limited | Electronic File | Piers Goodman: Environment Manager |
| Department of Mines, Industry Regulation and Safety | 1 electronic (EARS)<br>1 Hard Copy | TBA |

## Document Control

| Document Status | Prepared By | Authorised By | Date |
|---|---|---|---|
| Revision 1 | Clifford Bennison | Alan Wright | 1 November 2018 |
| Revision 2 | Jess Li | Alan Wright | 12 June 2019 |
| Revision 3 | Alan Wright | Kristy Sell | 8 July 2019 |
| Revision 4 | Karen Ganza | Kristy Sell | 5 September 2019 |
| Revision 5 | Karen Ganza | Kristy Sell | 3 October 2019 |
| Revision 6 | Karen Ganza | Alan Wright | 28 January 2020 |

# DMIRS Mine Closure Plan Checklist

| Item No | Question | Y/N /NA | Page No. | Comment | Change from prev version (Y/N) | Page No. | Summary |
|---|---|---|---|---|---|---|---|
| 1 | Has the Checklist been endorsed by a senior representative within the tenement holder/operating company? | Y | MCP Checklist | | N/A | | |
| **Public Availability** | | | | | | | |
| 2 | Are you aware that from 2015 all MCPs will be made publicly available? | Y | | | | | |
| 3 | Is there any information in this MCP that should not be publicly available? | N | | | | | |
| 4 | If "Yes" to Q3, has confidential information been submitted in a separate document/section? | | | | | | |
| **Cover Page, Table of Contents** | | | | | | | |
| 5 | Does the MCP cover page include:<br>• Project Title<br>• Company Name<br>• Contact Details (including telephone numbers and email addresses)<br>• Document ID and version number<br>• Date of submission | Y | Cover Page | | N/A | | |
| **Scope and Purpose** | | | | | | | |
| 6 | State why the MCP is submitted (e.g. as part of a Mining Proposal, a reviewed MCP or to fulfil other legal requirements) | Y | 1 | | N/A | | |
| **Project Overview** | | | | | | | |
| 7 | Does the Project summary include:<br>• Land ownership details<br>• Location of the Project;<br>• Comprehensive site plan(s);<br>• Background information on the history and status of the Project. | Y | 3 | | N/A | | |
| **Legal Obligations and Commitments** | | | | | | | |
| 8 | Does the MCP include a consolidated summary or register of closure obligations and commitments? | N | 8 | | N/A | | |
| **Stakeholder Engagement** | | | | | | | |
| 9 | Have all stakeholders involved in closure been identified? | Y | 13<br>Table 3 | | N/A | | |

| Item No | Question | Y/N /NA | Page No. | Comment | Change from prev version (Y/N) | Page No. | Summary |
|---|---|---|---|---|---|---|---|
| 10 | Does the MCP include a summary or register of historic stakeholder engagement with details on who has been consulted and the outcomes? | Y | 13 Appendix 1 | | N/A | | |
| 11 | Does the MCP include a stakeholder consultation strategy to be implemented in the future? | Y | Table 3 | | N/A | | |
| **Post-mining land use(s) and Closure Objectives** | | | | | | | |
| 12 | Does the MCP include agreed post-mining land use(s), closure objectives and conceptual landform design diagram? | Y | 19 | | N/A | | |
| 13 | Does the MCP identify all potential (or pre-existing) environmental legacies, which may restrict the post mining land use (including contaminated sites)? | Y | 28 | Pristine area by geological issues. | N/A | | |
| 14 | Has any soil or groundwater contamination that occurred, or is suspected to have occurred, during the operation of the mine, been reported to DWER as required under the *Contaminated Sites Act 2003*? | N | | No mine yet. | N/A | | |
| **Development of Completion Criteria** | | | | | | | |
| 15 | Does the MCP include an appropriate set of specific completion criteria and closure performance indicators? | Y | Table 4 | | N/A | | |
| **Collection and Analysis of Closure Data** | | | | | | | |
| 16 | Does the MCP include baseline data (including pre-mining studies and environmental data)? | Y | 28 | | N/A | | |
| 17 | Has materials characterisation been carried out consistent with applicable standards and guidelines? | Y | 52, 53 | | N/A | | |
| 18 | Does the MCP identify applicable closure learnings from benchmarking against other comparable mine sites? | N | | Knowledge indirectly influences closure designs / strategies – refer to page 85 | N/A | | |

| Item No | Question | Y/N /NA | Page No. | Comment | Change from prev version (Y/N) | Page No. | Summary |
|---|---|---|---|---|---|---|---|
| 19 | Does the MCP identify all key issues impacting mine closure objectives and outcomes? | Y | 78 | | N/A | | |
| 20 | Does the MCP include information relevant to mine closure for each domain or feature? | Y | 87 - 101 | | N/A | | |
| **Identification and Management of Closure Issues** | | | | | | | |
| 21 | Does the MCP include a gap analysis/risk assessment to determine if further information is required in relation to closure of each domain or feature? | Y | 85 | | N/A | | |
| 22 | Does the MCP include the process, methodology, and has the rationale been provided to justify identification and management of the issues? | Y | 78 | | N/A | | |
| **Closure Implementation** | | | | | | | |
| 23 | Does the MCP include a summary of closure implementation strategies and activities for the proposed operations or for the whole site? | Y | 85 | | N/A | | |
| 24 | Does the MCP include a closure work program for each domain or feature? | Y | 85 | | N/A | | |
| 25 | Does the MCP contain site layout plans to clearly show each type of disturbance as defined in Schedule 1 of the MRF Regulations? | N | | Final detailed site layout plan to be developed during detailed design | N/A | | |
| 26 | Does the MCP contain a schedule of research and trial activities? | Y | 86 | Preliminary trial activities identified. To be further developed during detailed design and operational phase | N/A | | |
| 27 | Does the MCP contain a schedule of progressive rehabilitation activities? | Y | 85 | | N/A | | |

| Item No | Question | Y/N /NA | Page No. | Comment | Change from prev version (Y/N) | Page No. | Summary |
|---|---|---|---|---|---|---|---|
| 28 | Does the MCP include details of how unexpected closure and care and maintenance will be handled? | Y | 97 | | N/A | | |
| 29 | Does the MCP contain a schedule of decommissioning activities? | Y | 87 | | N/A | | |
| 30 | Does the MCP contain a schedule of closure performance monitoring and maintenance activities? | Y | Table 30 | | N/A | | |
| **Closure Monitoring and Maintenance** | | | | | | | |
| 31 | Does the MCP contain a framework, including methodology, quality control and remedial strategy for closure performance monitoring including post-closure monitoring and maintenance? | Y | 101 | | N/A | | |
| **Financial Provisioning for Closure** | | | | | | | |
| 32 | Does the MCP include costing methodology, assumptions and financial provision to resource closure implementation and monitoring? | Y | 106 | | N/A | | |
| 33 | Does the MCP include a process for regular review of the financial provision? | Y | 107 | | N/A | | |
| **Management of Information and Data** | | | | | | | |
| 34 | Does the MCP contain a description of management strategies including systems and processes for the retention of mine records? | Y | 109 | | N/A | | |

**Corporate endorsement:**

I hereby certify that, to the best of my knowledge, the information within this Mine Closure Plan and checklist is true and correct and addresses all the requirements of the Guidelines for the Preparation of a Mine Closure Plan approved by the Director General of the Department of Mines, Industry Regulation and Safety.

| | | | |
|---|---|---|---|
| Name: | Piers Goodman | Signed: | Piers Goodman |
| Position: | Environment Manager | Date: | 28 January 2020 |

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Appendix 2: Sulphur Springs Soil Assessment (Outback Ecology 2013)
Appendix 3: Closure Risk Assessment
Appendix 4: TSF Preliminary Concept Design (KPC 2020)

# 1. SCOPE AND PURPOSE

This Conceptual Mine Closure Plan (MCP) has been prepared for the Sulphur Springs Zinc-Copper Project (Sulphur Springs or Project), owned by Venturex Resources Limited (Venturex). Sulphur Springs is a greenfields project 144 km southeast of Port Hedland and 57 km west of Marble Bar in the Pilbara Region of Western Australia (Marble Bar Mineral Field 45). The Project comprises:

- Development of an open pit to mine the top portion of the orebody.
- Development of an underground mine (accessed via a portal external to the pit) to mine deeper portions of the orebody.
- Construction and operation of a conventional processing plant to produce separate copper and zinc concentrates for export.
- Construction and operation of a 'valley fill' Tailings Storage Facility (TSF) for the placement of tailings.
- Construction of a waste rock dump (WRD) and additional elements such as internal roads and material stockpiles.
- Construction of support infrastructure including an accommodation village, wastewater treatment plants, mine water treatment plant, surface water management structures and power station.

The Sulphur Springs proposal is being assessed by the West Australian Environmental Protection Authority (EPA) under Part IV of the *Environmental Protection Act 1986 (EP Act),* at the level of Environmental Review - no public review.

This MCP has been prepared as an appendix to the Environmental Review Document (ERD) for the proposal in fulfilment of a requirement set by the EPA in an Environmental Scoping Document (EPA 2017).

The MCP outlines the approach and manner in which the rehabilitation and closure of the Project will be prepared for and implemented. While based on a substantial site specific data set, this early version of the MCP is necessarily conceptual in certain areas and Venturex anticipates refinement of the document as the detailed design of the Project is progressed. A refined version will accompany submission of a Mining Proposal to DMIRS for assessment under the *Mining Act 1978*.

The MCP has been prepared in accordance with the joint DMP/EPA *Guidelines for Preparing Mine Closure Plans* (May 2015 revision) (DMP/EPA 2015), which requires a risk-based approach to mine closure planning. The level of detail required in addressing rehabilitation and closure risks is commensurate with the level of the risk an influenced by the time to closure.

The structure of this MCP is:

Section 1: Outlines the scope and purpose of the MCP.

Section 2: Provides an overview of the history and status of Sulphur Springs, including land ownership, tenure, location, and an overview of the operations and main infrastructure components.

Section 3: Summarises the legal obligations and specific legally binding closure commitments relating to Sulphur Springs.

Section 4: Describes the process used to identify stakeholders relevant to mine closure, lists the stakeholders identified, provides a summary of engagement to date and outlines the approach to ongoing consultation in relation to mine closure.

Section 5: Identifies the post-mining land use and closure objectives based on the proposed land use.

Section 6: Describes the development of site-specific completion criteria by which success of closure will be measured.

Section 7: Provides environmental data relevant to closure, including a summary of baseline studies completed for Sulphur Springs. This includes information on the climatic conditions, geology, soils, waste and tailings characterisation, hydrogeology, hydrology, flora and fauna, social environment, rehabilitation and closure studies and key knowledge gaps.

Section 8: Provides a detailed description of the proposed Project.

Section 9: Outlines the risk assessment process for identifying the key closure issues and provides a summary of identified key risks and management measures.

Section 10: Provides a closure implementation plan, which includes:

- High level planned, unplanned and care and maintenance closure scenarios.
- Overview of Closure Domains.
- Work programs for all Closure Domains.
- High level closure milestones.
- Schedules for research.

Section 11: Describes the proposed environmental monitoring program and maintenance response requirements.

Section 12: Description of the process and methodology undertaken to estimated financial costs of closure for Sulphur Springs.

Section 13: Provides a description of how closure relevant information and data will be managed during ongoing closure planning and implementation.

# 2. PROJECT OVERVIEW

## 2.1 Ownership and Contact Details

Sulphur Springs is owned by Venturex Sulphur Springs Pty Ltd (ABN 11 113 177 432), a subsidiary of Venturex. Venturex is a Perth-based mineral resources developer, listed on the Australian Stock Exchange.

Correspondence related to this MCP should be addressed to:

**Name:** Piers Goodman
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**Title:** Environment Manager

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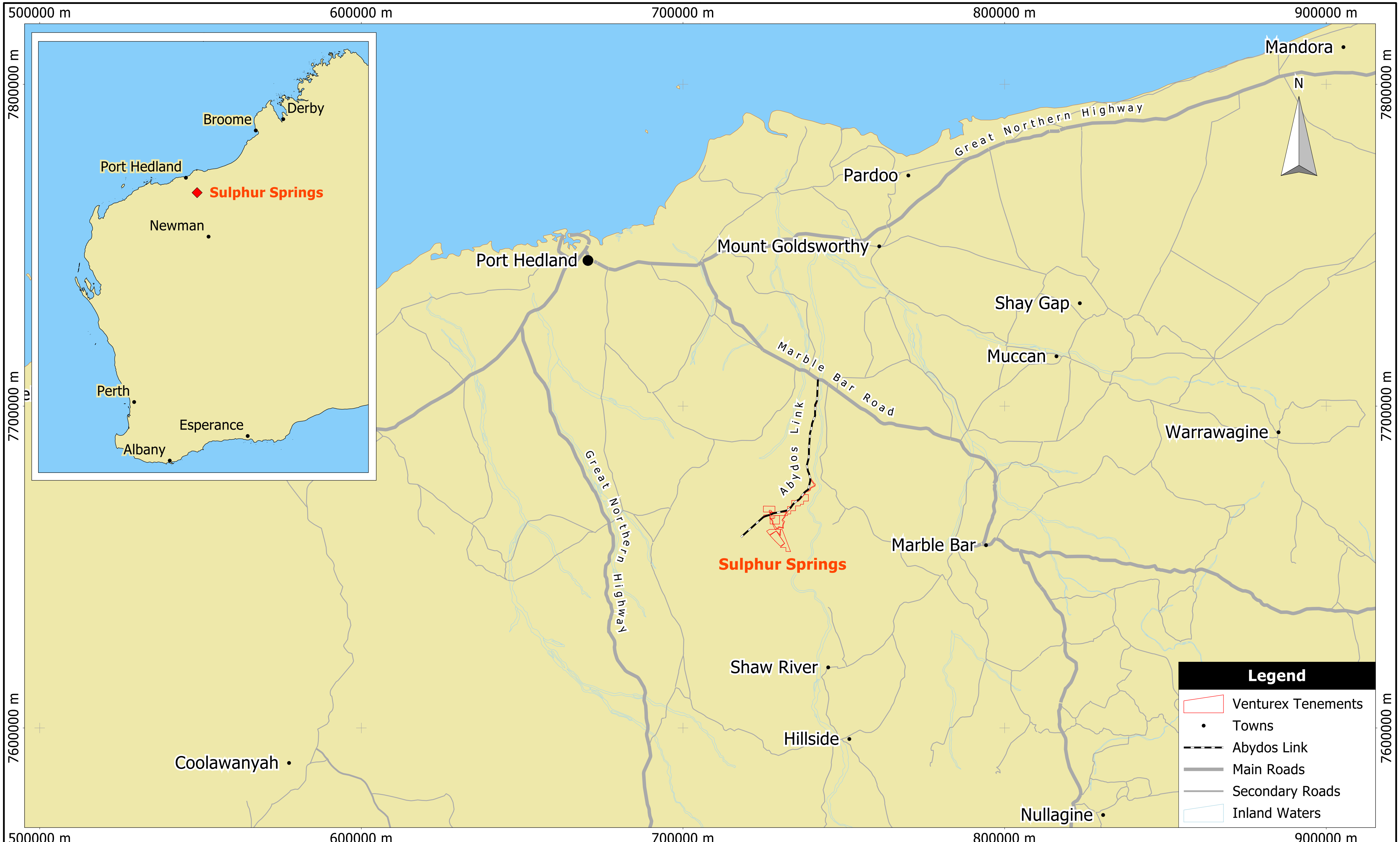
## 2.2 Location and Tenure

Sulphur Springs is 144 km southeast of Port Hedland and 57 km west of Marble Bar in the Shire of East Pilbara (Figure 1). The deposit and proposed mine is located on Unallocated Crown Land (UCL), and the northern section of the site access road and proposed accommodation village are on the Panorama and Strelley Pastoral leases.

Venturex holds a number of Mining and Miscellaneous Licenses over the area (Table 1 and Figure 2). The Project will sit wholly within mining leases M45/494, M45/653 and M45/1001 and miscellaneous licences L45/166, L45/170, L45/173, L45/179 and L45/189 (highlighted in Table 1)

**Table 1: Sulphur Springs Project Tenement Summary**

| Tenement | Area (Ha) | Holder | Granted | Expiry |
|---|---|---|---|---|
| M45/494 | 952 | Venturex Sulphur Springs Pty Ltd | 22/10/1990 | 21/10/2032 |
| M45/653 | 535 | Venturex Sulphur Springs Pty Ltd | 29/09/1995 | 28/09/2037 |
| M45/1001 | 861 | Venturex Sulphur Springs Pty Ltd | 22/01/2008 | 21/01/2029 |
| L45/166 | 2,183 | Venturex Sulphur Springs Pty Ltd | 01/05/2009 | 30/04/2030 |
| L45/170 | 688 | Venturex Sulphur Springs Pty Ltd | 185/08/2009 | 17/09/2030 |
| L45/173 | 40 | Venturex Sulphur Springs Pty Ltd | 24/08/2012 | 23/08/2033 |
| L45/179 | 637 | Venturex Sulphur Springs Pty Ltd | 01/04/2011 | 31/03/2032 |
| L45/188 | 57 | Venturex Sulphur Springs Pty Ltd | 20/11/2009 | 19/11/2030 |
| L45/189 | 1,808 | Venturex Sulphur Springs Pty Ltd | 20/11/2009 | 19/11/2030 |
| L45/287 | 117 | Venturex Sulphur Springs Pty Ltd | 28/09/2012 | 27/09/2033 |

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Venturex Resources Limited
Sulphur Springs Project

**Figure 1**

**Location Plan**

4 Cook St
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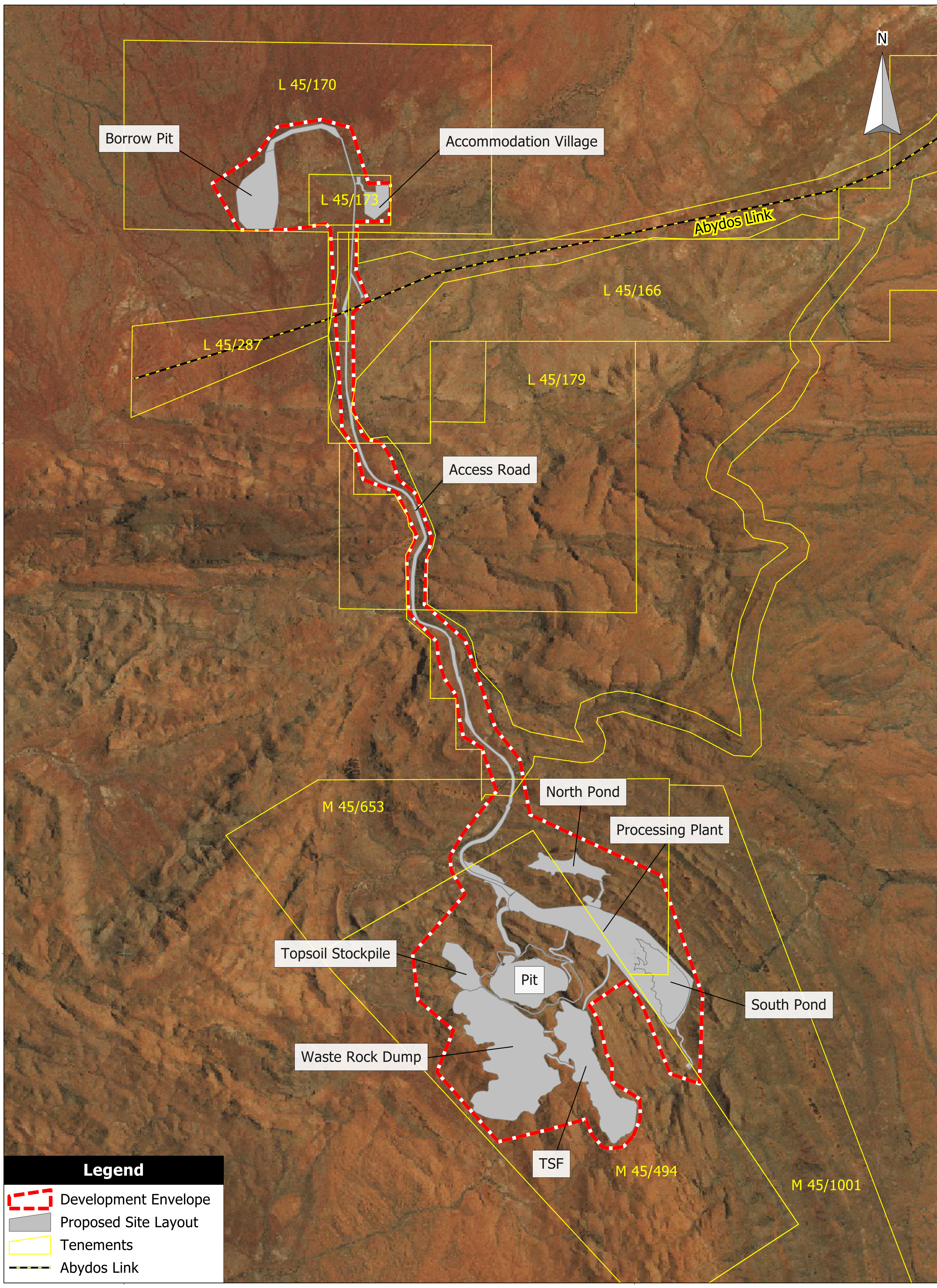
MBS ENVIRONMENTAL

W:\Venturex Resources\Sulphur Springs\Projects\2018 ERD\Drawings\Location Plan.map 28/01/2020 MCP F1 Location Plan A4L

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Venturex Resources Limited
Sulphur Springs Project

**Figure 2**

**Development Envelope and Tenement Plan**

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MBS ENVIRONMENTAL

## 2.3 Project Description

Sulphur Springs is a volcanogenic massive sulphide zinc-copper deposit predominantly within the Gorge Ranges (Figure 1). Base metal sulphide mineralisation was first discovered at the site in 1991. Since this time, a number of exploration programs, studies and reviews have been conducted to further define the resource, understand the receiving environment and develop a viable project development concept. These studies include:

- A detailed feasibility study of the Project by CBH Sulphur Springs Pty Ltd (CBH) in 2007, which identified that the total resource could be economically, mined by a 43 million Bank Cubic Metre (BCM) open pit mine and associated WRDs with an indicative Project footprint of 590 ha. CBH submitted a Public Environmental Review (PER) for the development to the EPA in 2007. Following the purchase of CBH by Toho, the Project was sold to Venturex in 2010. The assessment process was terminated by the EPA at the request of Venturex on 2 July 2012.
- A detailed feasibility study of the Project by Venturex in 2012, based on mining the total resource using an underground mine. A Mining Proposal and Mine Closure Plan for this option was assessed and approved by the Department of Mines, Industry Regulation and Safety (DMIRS, previously known as the Department of Mines and Petroleum (DMP)) in 2014 and included a 1.0 Mtpa underground mine, 1 Mtpa processing plant, site access roads and transport corridors, accommodation village and airstrip and associated elements. No activities approved under this Mining Proposal (Reg ID 40542) and associated clearing permit (CPS 5658/1) have been implemented to date.
- Further optimisation studies by Venturex between 2015 and 2020, based on mining the resource via an open pit and underground mine. This forms the basis of the current Project design.

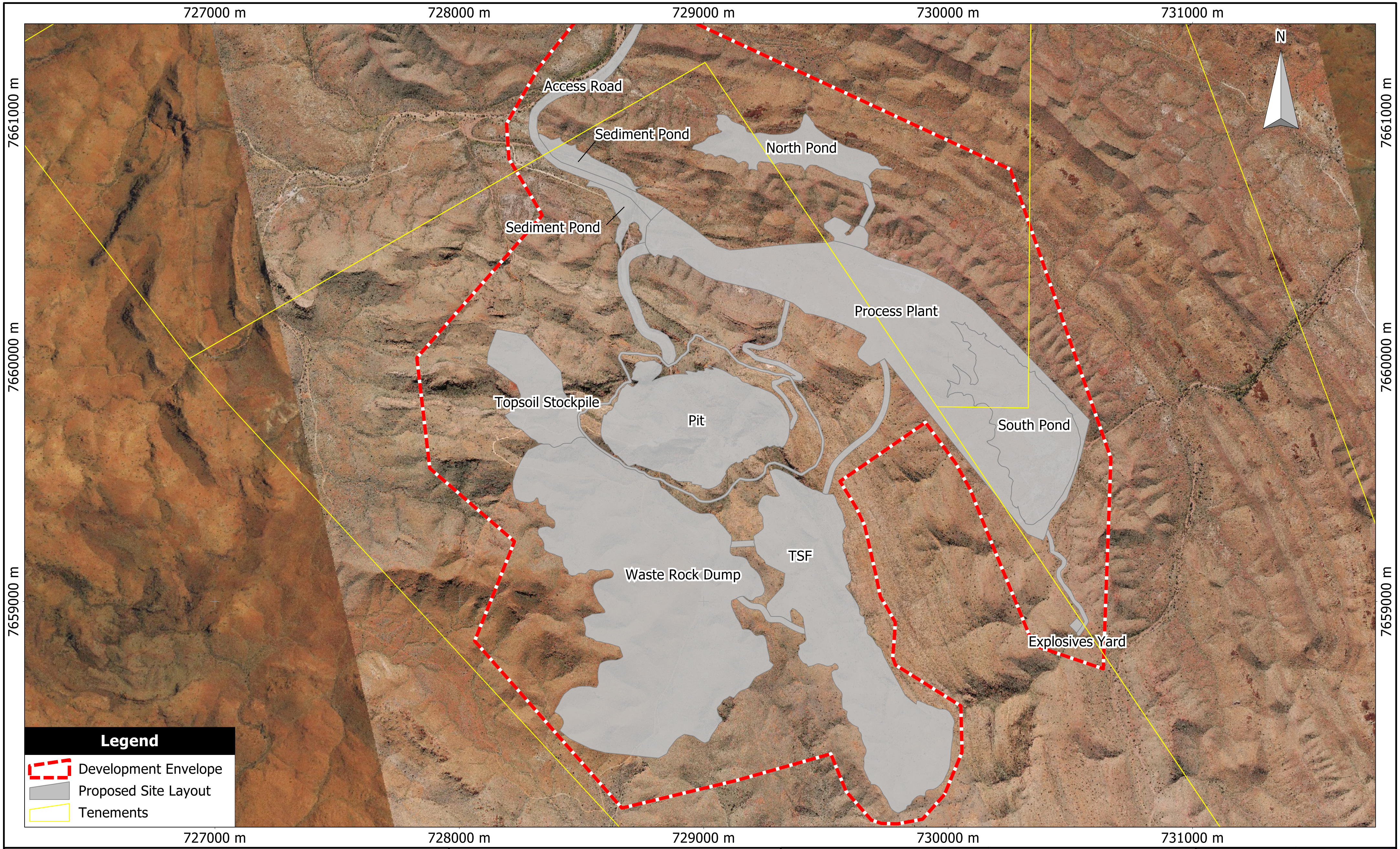
The current Project comprises:

- Development of an open pit and subsequent underground mine mined at rates up to 1.5 Mtpa
- Construction and operation of a 1.5 Mtpa conventional flotation processing plant to produce copper and zinc concentrates for export.
- Storage of tailings in a 'valley fill' TSF within the pit catchment, with minor quantities of tailings stored underground.
- Construction of a waste rock dump (WRD).
- Construction of associated mine elements (stormwater management infrastructure (bunds and drains), water storage/evaporation ponds, mine roads, site access road, growth medium and vegetation stockpiles, construction material stockpiles, power station, accommodation village and mine support facilities).

The estimated life of mine (LOM) is 10 years, with the prospect of extension. Primary post-closure landforms will include:

- An open pit, approximately 450 wide, 645 long and 150 m deep in which a pit lake is expected to form after mine dewatering ceases.
- A TSF that will largely infill the valley upstream of the pit. The TSF will be designed as water shedding, discharging storm runoff to adjacent catchments and away from the mine pit.
- A WRD landform which will infill the valley to the south west of the pit. The final slopes of the WRD will be shaped to direct surface runoff away from the pit.
- The pit abandonment bund and any stormwater diversion structure located within the mine pit shell.

The conceptual site layout is shown in Figure 3 and further details of the Project are provided in Section 8.




| | | | |
|---|---|---|---|
| Scale: 1:20000<br>Original Size: A4<br>Air Photo Date: 2019<br>Grid: MGA94(50)<br>0 — 500 m | Venturex Resources Limited<br>Sulphur Springs Project | **Figure 3**<br>**Site Layout** | Martinick Bosch Sell Pty Ltd<br>4 Cook St West Perth WA 6005<br>Australia<br>t:+61 8 9226 3166<br>info@mbsenvironmental.com.au<br>www.mbsenvironmental.com.au<br>MBS ENVIRONMENTAL |

W:\Venturex Resources\Sulphur Springs\Projects\2018 Mine Closure Plan\Drawings\Sulphur Springs MCP (from ERD) V6.map 24/01/2020 F3 Site Layout Layout

# 3. IDENTIFICATION OF CLOSURE OBLIGATIONS AND COMMITMENTS

## 3.1 Overview

DMIRS is the lead regulator and decision-making authority for mining projects in Western Australia under the *Mining Act and* has particular responsibility for mine closure. Where mining projects are of a scale or nature that is considered “significant”, they are referred to the EPA for assessment under Part IV of the *EP Act*, in accordance with a Memorandum of Understanding (MoU) between the two agencies (DMP/EPA 2016). Sulphur Springs is currently subject to assessment by the EPA.

A brief summary of the principal relevant instruments and legislation, and current or expected obligations for closure of Sulphur Springs, is provided in the sections below. A register of obligations relevant to Project closure will be incorporated into future revisions of this MCP, as regulatory approvals are obtained.

## 3.2 Native Title Agreement

The Project lies largely within the claimant area of the Nyamal people. A Mining Deed was executed on 3 November 2006 with the Nyamal people and provides for regular consultation and participation in the provision of cultural awareness training, site clearances, direct employment and provision of contract services.

## 3.3 Environmental Protection and Biodiversity Conservation Act

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) requires referral of projects with the potential to significantly impact upon Matters on National Environmental Significance (MNES) to the Federal Department of the Environment and Energy (DoEE). A prior form of the Project was referred in June 2013 to DoEE (previously Commonwealth Department of Sustainability, Environment, Water, Population and Communities) and in July 2013 the DoEE determined that the Project was not a controlled action and did not require formal assessment under the *EPBC Act*. The current Project is not considered to constitute a risk of significant impact on MNES and is not subject to approval obligations under this legislation.

## 3.4 Environmental Protection Act

### 3.4.1 Part IV Assessment

Venturex referred Sulphur Springs to the EPA under Part IV of the *EP Act* in December 2016 (MBS 2016). The EPA determined that the Project would be assessed through an Environmental Review with no public review process (Assessment No. 2120), identifying several preliminary environmental factors: Terrestrial Environmental Quality and Inland Waters Environmental Quality, Flora and Vegetation and Subterranean Fauna. This MCP is a requirement of the environmental scoping document prepared by the EPA for the assessment and is included as an appendix of the Environmental Review Document.

### 3.4.2 Part V Assessment

A Works Approval and Environmental Licence is required to construct and operate the processing plant, TSF and other infrastructure prescribed under Part V of the *EP Act*. This part of the *EP Act* is administered by the Department of Water and Environmental Regulation (DWER) and provides for regulation to control emissions with the potential to cause pollution.

Monitoring data (such as TSF seepage monitoring) typically required by operating licences is likely to be relevant to closure and is discussed further in Section 11. Part V of the *EP Act* allows DWER to issue a “closure notice” requiring ongoing management and monitoring of a licensed premise after operations cease and the licence is relinquished, if DWER believes that there are still hazards to human health and/or the environment.

Clearing Permits issued under Part V typically set conditions for revegetation when the disturbed land is no longer required for the intended purpose. As clearing for the Project will be assessed under Part IV of the *EP Act*, no Clearing Permits are required.

## 3.5 Mining Act

### 3.5.1 Tenement Conditions

The Project tenements are granted under the *Mining Act* and subject to conditions administered by DMIRS Resource and Environmental Regulation directorate. Conditions of the Project tenements relevant to closure are typical of tenements granted in Western Australia, and broadly incorporate obligations to:

- Cap, fill, or otherwise make safe all exploration drill holes immediately after completion.
- Rehabilitate exploration disturbances within six months of completing the exploration program, except where otherwise authorised by DMIRS.
- Remove topsoil ahead of construction or mining and stockpile it.
- Except where otherwise authorised by DMIRS, at the completion of operations or progressively where possible:
  - Replace stockpiled topsoil.
  - Remove all wastes, equipment, structures and installations.
  - On the completion of operations or progressively when possible, all waste dumps, tailings storage facilities, stockpiles or other mining related landforms must be rehabilitated to form safe, stable, non-polluting structures which are integrated with the surrounding landscape and support self-sustaining, functional ecosystems comprising suitable, local provenance species or alternative agreed outcome to the satisfaction of the Executive Director, Environment Division, DMIRS.

### 3.5.2 Mining Proposal Commitments

The Project tenements, like other tenements issued under the *Mining Act*, require that a plan of proposed operations and measures to safeguard the environment, in the form of a Mining Proposal, is authorised by DMIRS before any development or operation begins. On approval, conformance to the measures set out in the Mining Proposals becomes a tenement condition. Since 2010, the *Mining Act* has required that Mining Proposals are accompanied by an MCP, to address measures related to closure and rehabilitation.

Venturex will submit a Mining Proposal for the Project after completion of detailed project design which will follow conclusion of the Part IV *EP Act* assessment.

## 3.6 Mines Safety and Inspection Act

The *Mines Safety and Inspection Act 1994* (MSIA) and *Regulations 1995* (MSIR), administered by the DMIRS Resources Safety Branch regulate mine worker and public safety at mine sites during construction, operations, any suspension of operations, decommissioning and rehabilitation works, and following mine abandonment. While safety on mines is primarily regulated under the MSIR, operations are also subject to the broader *Occupational Health and Safety Regulations 1996* (OHSR).

Under *MSIA s42, MSIR s3.14, and MSIR s3.16*, Venturex is required to notify DMIRS of any intention to suspend or abandon operations at Sulphur Springs. Venturex must also prepare and submit a plan (known as a Care and Maintenance Plan) addressing how the site will be:

- Cared for and maintained during any period of suspension.
- Kept safe for any remaining workers, through maintenance of emergency and other services.

- Made safe for the public, by preventing unauthorised or inadvertent access to hazardous areas, preventing post-mining subsidence, and removing hazardous plant, equipment, and materials.

The MSIR require that mines operate according to a Project Management Plan, approved by DMIRS Resources Safety Branch. The Project Management Plan sets out how mine worker and public safety is managed over the life of operations and must be updated for any material change in the configuration or status of operations, including suspensions, decommissioning, and rehabilitation. Suspension (care and maintenance) and unplanned closure are addressed in Section 1.1.1.

## 3.7 Mining Rehabilitation Fund Act

The *Mining Rehabilitation Fund Act 2012* requires tenement holders to report areas of exploration and mining disturbance every year to the State Mining Rehabilitation Fund (MRF), administered by DMIRS. DMIRS then invoices the tenement holder for a contribution to the MRF, based on rates set by the *Mining Rehabilitation Fund Regulations 2013,* reflecting expected typical closure costs for different types of disturbance (DMP 2013b).

Disturbances on which rehabilitation works have been completed, and completion criteria have been met, attract a lower contribution rate, providing an incentive for early or progressive rehabilitation. Once verified by DMIRS, such areas require no further contribution. DMIRS retains the ability to impose bonds for sites considered a high risk, for instance due to a poor history of compliance, or inadequate progress on mine closure.

Venturex currently reports to the MRF for the existing disturbance on its tenements and will report on new disturbance for Sulphur Springs as it is developed.

## 3.8 Rights in Water and Irrigation Act

Licences to Take Water issued for Venturex tenements under Section 5C of *Rights in Water and Irrigation Act 1914* (*RIWI Act*) are summarised in Table 2.

**Table 2: Licences to Take Water for Venturex Tenements**

| Details | Licence Number | |
|---|---|---|
| | GWL 165207 | GWL 176408 |
| Venturex Tenement/s | M45/494, M45/1001, M45/653 | L45/189 |
| Licence Holder | Venturex Sulphur Springs Pty Ltd | Atlas Iron Limited |
| Annual Water Entitlement | 150,000 kL | 1,198,368 kL |
| Purposes | General campsite purposes, dust suppression for mining purposes, mineral exploration activities | Dust suppression, earthwork and construction, potable water supply |
| Expiry | 30/04/2028 | 16/01/2025 |

Venturex will apply for an amendment to GWL 165207 to allow mine dewatering and use of water from the pit area and discuss licence transfer options for GWL 176408 with Atlas Iron Limited (an agreement between Atlas Iron Limited and Venturex provides for cooperation on groundwater entitlements and infrastructure). Further Permits to Construct or Alter Wells (Section 26D) will be sought for any future bore development that may be required.

No conditions directly related to closure and rehabilitation are typically imposed by such licences or permits. Venturex must notify DWER of any significant changes to the approved Project water scheme, including decommissioning or transfer of water supply bores or related infrastructure at closure, or changes to tenure or ownership. DWER generally requires water bores to be decommissioned according to Australian guidelines (NUDC 2012).

Water abstraction and use under the licence will be managed and monitored according to an approved Groundwater Operating Strategy (GWOS) to ensure that environmental values are appropriately protected from the impacts of abstraction. Monitoring will incorporate abstraction volumes, levels and quality and while this is primarily for operational purposes, the data collected will be relevant to closure.

The project is in the proclaimed Pilbara Surface Water Area. Venturex will liaise with DWER to determine whether a permit to interfere with the bed an banks of a watercourse will be required under Section 17 of the *RIWI Act* to provide, in particular, for the construction of the mine pit and access road.

### 3.9 Contaminated Sites Act

Land owners, occupiers and polluters are obliged to report any known or suspected site that may present a material hazard to human health or the environment, as defined by the *Contaminated Sites Act 2003* (*CS Act*), to DWER. DWER may require an investigation and depending on the outcome of the investigation, remediation.

If contamination does not present an immediate threat, remediation may often be left until closure, subject to consultation with DWER. Liability for any contamination under the *CS Act* is however separate to obligations under the *Mining Act* and can remain even after the site is relinquished and tenements extinguished.

Sulphur Springs is a “greenfields” site and existing contamination is unlikely (the site of the mine pit naturally discharges acidic water containing elevated metals and metalloids). Several aspects of Project construction and operation have potential to create liabilities under the *CS Act* if not properly managed. These include spills of hydrocarbons, reagents and process solutions, and seepage from the TSF and waste rock dump.

Section 10.2.4 outlines the proposed approach to construction, operation and closure of these facilities to limit the risk of contamination.

### 3.10 Corporations Act and ASX Rules

Venturex, as a company registered in Australia and regulated under the *Corporations Act 2001 (Cth) (Corporations Act),* is required to maintain accounts and prepare financial statements in accordance with the standards set by the Australian Accounting Standards Board (AASB). These standards require liabilities of uncertain timing or amount to be treated in company financial statement as “provisions”. Such liabilities are typically taken to include decommissioning and rehabilitation obligations. The *Corporations Act* is administered by the Australian Securities and Investments Commission (ASIC). Provisions for closure obligations are discussed in Section 12. Venturex will apply relevant aspects of the International Financial Reporting Standards (IFRS) for mine closure costs, where consistent with AASB standards.

As a public company listed on the Australia Stock Exchange (ASX), Venturex is bound by periodic disclosure rules that require quarterly, half-yearly and annual reports to the market with financial statements listing all significant assets and liabilities according to AASB standards. Continuous reporting rules apply for changes in circumstance with a material effect on the expected value of the company; such circumstances may include suspension of operations, changes to the expected LOM, or early closure.

### 3.11 Other Instruments and Legislation

Other instruments or legislation with a bearing on closure of Sulphur Springs include:

- *Land Administration Act 1997,* administered by the Department of Planning, Lands and Heritage (DPLH), and governing overall land tenure and access in Western Australia, including the management of Pastoral Leases. Under this Act, the department has an interest in the condition of the land post mining, in part to ensure there are no ongoing safety risks requiring management. Proposed amendments to this Act may present opportunities for alternative post-closure land uses.

- *Aboriginal Heritage Act 1972*, administered by the DPLH for the protection of sites, places and artefacts of significance to Aboriginal culture in Western Australia. Surveys to date (Section 7.10.2) indicate that no known sites of significance need be disturbed by the Project. Obligations exist to report and take steps to protect any sites identified in the course of Project construction, operation and closure.
- Local government regulations administered by the Shire of East Pilbara, including planning, building, sewage, and health regulations. The Shire also requires notice of building, decommissioning or demolition works.
- *Biosecurity and Agriculture Management Act 2007 and Regulations 2013*, administered by the Department of Agriculture and Food (DAF), regulating the control of animal and plant pests in Western Australia.

Venturex will monitor changes in relevant legislation and incorporate any new or changed obligations with a substantial bearing on closure in the obligations register and revisions of this MCP.

## 3.12 Voluntary Standards

### 3.12.1 Strategic Framework for Mine Closure

Venturex intends to adopt as far as practicable the principles for mine closure as set out in the *Strategic Framework for Mine Closure* (ANZMEC/MCA 2000) and recognised by DMIRS in the MCP guidelines. These broad principles state that closed mines should be left:

- *Safe*, with no substantial public risk remaining.
- *Stable*, with mining landforms resistant to mass movement like landslips, and surface erosion reduced to a practicable minimum.
- *Non-polluting,* with sources of pollution like metalliferous tailings or acid-forming waste rock appropriately contained.
- *Empathetic to the surrounding landscape*, with post-mining landforms blending in with the natural landscape.

In addition, the principles state that post-mining landforms should be *economic to construct* and *require minimal ongoing maintenance*, reducing closure costs while meeting regulatory obligations and standards.

Venturex will consider these principles in setting closure objectives (Section 5) and developing completion criteria (Section 6) for Sulphur Springs.

### 3.12.2 Venturex Human Resources Policies

Venturex will develop human resources policies for Sulphur Springs, including policies to address the suspension or closure of the operations and mitigate the impact on its workforce. Venturex will as far as is practicable and reasonable:

- Keep workers informed of any potential decision to suspend or close the operations before the expected end of the LOM, and any changes to the expected LOM schedule.
- Retain mine workers for decommissioning and rehabilitation works, although it is recognised that many may chose to leave for longer-term employment once the decision to close has been announced.
- Provide counselling, support and advice where appropriate on job-seeking, re-training and financial management.
- Advise workers on their rights and benefits payable under relevant employment legislation, contracts of employment, and Venturex policies.

# 4. STAKEHOLDER ENGAGEMENT

## 4.1 Principles

Venturex has engaged with stakeholders throughout the progression in design, study and permitting (ongoing) of the Project. Consultation has involved parties with a significant interest in the closure and rehabilitation of the Project. A list of stakeholders is maintained, to ensure that relevant parties have been identified and their interests considered in the ongoing development of Project plans.

Details of the stakeholder consultation are provided below, including consultation objectives, identification of key stakeholders and consultation to date.

## 4.2 Principal Stakeholders

Principal stakeholders identified to date, their main interests and concerns, and the primary means of engagement or communication are summarised in Table 3 and discussed in the following sections Consultation has taken the form of written correspondence, briefings/presentations, meetings, workshops and telephone discussions.

## 4.3 Engagement to Date

### 4.3.1 Overview

To date, engagement and consultation on closure planning has been undertaken largely as part of the broader approvals processes. While there has been some closure-specific consultation relating to post-mining land use and cultural values, at this stage of the Project it is assumed that mine closure planning will be addressed in keeping with relevant regulations, guidelines, and industry conventions.

Stakeholder consultation to date is summarised in Appendix 1, and discussed below. As the Project matures, Venturex will undertake specific consultation relating to closure matters.

### 4.3.2 Nyamal People

The Nyamal people hold native title rights and interests over the land on which the Project is situated. Engagement and consultation between Venturex and the Nyamal people to date has broadly incorporated:

- Meetings, correspondence and phone calls with various representatives and Indigenous Services.
- Site visit with Venturex personnel to outline Project infrastructure, visit heritage sites and discuss the relative cultural significance of the area.
- Participation in a cultural awareness training course run by the Nyamal people.

### 4.3.3 Environmental Protection Authority and EPA Services

Engagement and consultation between Venturex and the EPA to date has broadly incorporated:

- Pre-referral meetings to provide an overview of the proposed Project and identify potential key environmental factors.
- Submission of proposal referral and environmental review documentation and subsequent revisions. Discussions and submissions of supplementary information.
- A workshop focussed on post closure risks attended by regulatory agencies and specialist consultants.
- Submission of requests to vary the referred proposal under Section 43a of the *EP Act* to refine the Project and attend to post-closure risks.

#### 4.3.4 DMIRS Resource and Environmental Regulation Directorate

Engagement and consultation between Venturex and DMIRS to date has broadly incorporated:

- Meetings with DMIRS during 2015 and 2016 to discuss the Project and outline key changes since Mining Proposal (REG ID 40542) was approved. These meetings also provided opportunity to consider the approvals pathway and identify matters to be addressed in an approval submission.
- Various meetings with DMIRS between January and May 2017 to discuss items in the Sulphur Springs EPA Referral (submitted to OEPA in December 2016). These meetings focussed particularly on construction and closure designs for the TSF and included a TSF options assessment workshop attended by representatives from DMIRS Minerals Environment and Geotechnical Branches, Department of Water (now DWER) and Department of Environment Regulation (now DWER).
- Several meetings, phone conversations and emails between November 2017 and February 2019 to discuss aspects of closure planning including closure objectives and criteria, closure strategies and ongoing monitoring.
- Several meetings and emails between October and December 2019 regarding changes to the proposal including an alternative TSF site, construction of two evaporation ponds and removal of a heap leach facility.

#### 4.3.5 Department of Water and Environmental Regulation

Engagement and consultation between Venturex and DWER to date has included:

- Meeting with DMIRS and representatives from Department of Water and Department of Environment Regulation (now DWER) in February 2017 to discuss TSF closure options.
- Meetings with representatives from DWER and EPA Services in September and November 2019 to discuss TSF design and operation, water treatment plant design, ecological risks associated with the Project (September) and inform of the decision to relocate the TSF (November).
- Meeting with representatives from DWER in December 2019 to provide a briefing on the rationale to relocate the TSF, initial study outcomes of the new TSF design and discuss Part V requirements and timing.

#### 4.3.6 Department of Biodiversity, Conservation and Attractions

Engagement and consultation between Venturex and the Department of Biodiversity, Conservation and Attractions (DBCA) has included a meeting with the Department of Parks and Wildlife (now DBCA) in March 2016 to discuss the Project and conservation significant flora and fauna species in the region including *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4), Northern Quoll (*Dasyurus hallucatus*) and Pilbara Leaf Nosed Bat (*Rhinonicteris aurantia*).

#### 4.3.7 Other Stakeholders

Other stakeholders or potential stakeholders engaged or consulted by Venturex to date include:

- Shire of East Pilbara: including invitation to comment on the proposed Project, identification of Shire approvals required, and consultation on the use of or changes to public roads.
- Pilbara Development Commission: Consultation on post-mining land use opportunities.
- Pastoralists: various consultations with Strelley, Panorama and Hillside Stations.
- Atlas Iron Limited: meetings and correspondence to discuss information sharing and synergies between the Sulphur Springs and Abydos Projects.
- Fortescue Metals Group: meetings and correspondence to discuss information sharing and synergies between the Sulphur Springs and North Star Projects.

To date, none of these parties has raised particular concerns or declared interests directly related to mine closure.

**Table 3: Principal Stakeholders and Engagement**

| Stakeholder | Main Interests or Concerns | Means of Engagement |
|---|---|---|
| **Regulatory** | | |
| Environmental Protection Authority (EPA) & EPA Services | • Conservation of biological diversity and ecological integrity.<br>• Ecologically sustainable construction, operation, decommissioning and rehabilitation of minerals operations.<br>• Protection of species, communities and landforms of conservation significance. | • Referral under *EP Act* Part IV.<br>• Submission of ERD, including a MCP, for assessment under *EP Act* Part IV.<br>• Ongoing fulfilment of Ministerial Conditions, subject to outcome of Part IV assessment.<br>• Briefings, meetings, revised proposal design in response to comments, queries |
| Department of Mines, Industry Regulation and Safety (DMIRS) | • Compliance with *Mining Act* and tenement conditions.<br>• Conformance to MCP and Mining Proposals.<br>• Suitability of closure criteria for intended final land uses.<br>• Effectiveness of rehabilitation studies, designs, and techniques.<br>• Relinquishment of tenure under *Mining Act*.<br>• Payment of MRF contributions.<br>• Compliance with MSIA and MSIR.<br>• Compliance with Project Management Plan.<br>• Mine worker health and safety during suspensions, decommissioning and rehabilitation.<br>• Public safety during suspensions and after closure.<br>• Maintaining records of closed mine workings for safety of future mining operations. | • Submission of Mining Proposals and MCP for assessment under *Mining Act*.<br>• Annual reporting of closure planning and rehabilitation under tenement conditions (AER).<br>• Submission of MCP revisions under tenement conditions.<br>• Annual submission of disturbed and rehabilitated areas under MRF.<br>• Annual inspections and related correspondence.<br>• Submission of mines safety notices.<br>• Submission and update of Project Management Plan.<br>• Annual inspections and related correspondence.<br>• Incident, exposure and health reporting under MSIR.<br>• Participation in regular mine closure progress meetings.<br>• Submission of mines safety notices, including notices of suspension, recommencement, or closure.<br>• Submission of mine plans at suspension or closure.<br>• Briefings, meetings, revised proposal design in response to comments, queries |

| Stakeholder | Main Interests or Concerns | Means of Engagement |
|---|---|---|
| Department of Water and Environmental Regulation (DWER) | • Compliance with *RIWI Act*.<br>• Sustainability of abstraction and management of drawdown impacts during operations.<br>• Impact on water resources.<br>• Restoration of surface water flows after closure.<br>• Decommissioning or handover of bores.<br>• Compliance with *EP Act* Part V, and Works Approval and Prescribed Premises Licence conditions (primarily operational).<br>• Prevention, monitoring and remediation of pollution.<br>• Compliance with *CS Act*.<br>• Reporting, investigation, remediation and validation of contaminated sites.<br>• Maintenance of contaminated sites records. | • Application for groundwater licences under *RIWI Act*, and submission of supporting GWOS.<br>• Annual groundwater monitoring reports (GMR) under groundwater licence conditions.<br>• Invitation to comment on MCP and any related groundwater modelling.<br>• Invitation to comment on post-closure groundwater monitoring.<br>• Bore decommissioning reports and/ or applications to transfer licence.<br>• Submission of Works Approval and Licence applications.<br>• Meetings regarding proposal design, regulatory processes<br>• Annual reporting of pollution monitoring and compliance under licence conditions.<br>• Contingency notification of major spills and clean-up.<br>• Submission of contaminated sites notices and investigation reports under *CS Act*, if required.<br>• Submission of remediation and validation reports under *CS Act*, if required. |
| Department of Biodiversity, Conservation and Attractions (DBCA) | • Compliance with *Biodiversity Conservation Act 2016* (*BC Act*).<br>• Flora, fauna and habitat conservation.<br>• Interest in projects that are on DBCA managed land only.<br>• Baseline surveys and licences to take flora and fauna. | • Invitation to comment on MCP. |
| Geological Survey of Western Australia (GSWA) | • Access to potential future resources including old mine wastes.<br>• Maintenance of geological records for future explorers/ miners. | • Submission of geological data and resource sterilisation reports. |

| Stakeholder | Main Interests or Concerns | Means of Engagement |
|---|---|---|
| Department of Planning, Lands and Heritage (DPLH) | • Transfer of assets, infrastructure (particularly post closure engineered surface drainage control structures) and tenure.<br>• Changes to land use<br>• Management of public risk on UCL. | • Invitation to comment on final MCP.<br>• Meeting to provide project update and key project characteristics regarding closure and final land use (on UCL). |
| Nyamal People | • Compliance with Mining Deed.<br>• Protection of sites or features of heritage significance.<br>• Post closure land use and access.<br>• Employment and commercial opportunities/cooperation of benefit to the local community. | • Provision of draft approval documents for review and comment (including MCP).<br>• Involvement in cultural awareness training, site clearances, environmental monitoring programs.<br>• Regular consultation to provide updates on progression of Project and explore collaboration opportunities. |
| Panorama and Strelley Pastoral Leases | • Land management (weeds, feral animals, fire).<br>• Air and noise emissions at Mine Site.<br>• Interaction with pastoral activities, including livestock safety on roads.<br>• Access to water bores as water supply for cattle.<br>• Post mining land use. | • Invitation to comment on MCP and AERs.<br>• Notification of planned or unplanned suspension or closure.<br>• Other correspondence as required. |
| Shire of East Pilbara and Town of Port Hedland | • Compliance with building, health, sewage and other local government regulation.<br>• Payment of rates.<br>• Future land use and access.<br>• Potential handover of infrastructure such as roads for ongoing use.<br>• Benefits to local economy and community.<br>• Safety of locals and passers-by during suspensions and after closure. | • Invitation to comment on MCP and AERs.<br>• Notification of planned or unplanned suspension or closure.<br>• Notices of decommissioning and demolition works. |
| Atlas Iron Limited | • Maintenance and use of shared infrastructure including Abydos link and abstraction bores. | • Correspondence as required. |

| Stakeholder | Main Interests or Concerns | Means of Engagement |
| --- | --- | --- |
| Non-Governmental Organisations (NGOs) | • Interest in impacts to flora and fauna, particularly species of conservation significance such as Northern Quoll, Pilbara Leaf Nosed Bat, Ghost Bat and *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4).<br>• Water abstraction and use and impacts on potential Groundwater Dependent Ecosystems (GDEs).<br>• National heritage values.<br>• Post mining land use and rehabilitation.<br>• Impacts on ecotourism ventures. | • Notification of planned or unplanned suspension or closure.<br>• Other correspondence as required. |
| **Commercial/Internal** | | |
| Venturex Board and Management Team | • Compliance with legal obligations.<br>• Costs of decommissioning and rehabilitation works.<br>• Planning and management of decommissioning and rehabilitation<br>• Feasibility, practicability, safety management and effectiveness of closure designs and methods.<br>• Cost recovery through scrap, salvage, and/or transfer of assets and liabilities in place. | • Internal management closure workshops with technical consultants.<br>• Internal review of MCP and revisions.<br>• Internal review of expected closure costs and provisions. |
| Security Holders | • Current and future assets and liabilities.<br>• Costs of decommissioning and rehabilitation.<br>• Compliance with legal obligations. | • Annual shareholder report, incorporating closure liabilities and provisions.<br>• Periodic ASX reports, including substantial movements in closure liabilities and provisions. |
| Venturex Employees | • Expected life of operations.<br>• Employment in decommissioning and closure works.<br>• Transition to alternative employment. | • Pre-shift meetings and announcements.<br>• Newsletters. |
| Contractors | • Expected life of operations.<br>• Ownership of assets and liabilities, including scrap, salvageable parts, and serviceable equipment.<br>• Responsibilities for clean-up and disposal of contaminated materials, wastes, scrap, and salvageable parts.<br>• Contracts for closure and rehabilitation work. | • Contract documents, meetings, and related correspondence.<br>• Tender documents for closure and rehabilitation works. |

# 5. POST-MINING LAND USE AND CLOSURE OBJECTIVES

## 5.1 Post-mining Land Use

The current targeted post-mining land uses for the Sulphur Springs Project area are: (i) on UCL – a return to a naturally vegetated terrain that includes a pit lake which acts a 'groundwater sink' and (ii) on pastoral leases – return to low intensity grazing. The aim is to return the land as best possible to a condition and post-mining use similar to that surrounding the Project footprint. This aligns with the DMIRS guideline (DMP 2015) stating that post-mining land use must be:

- Relevant to the environment in which the mine operates.
- Achievable in the context of post mining land capability.
- Ecologically sustainable in the context of the local and regional environment.

Figure 2 shows the existing land use for site elements, which, with the exception of a pit lake, will be restored post-mining. During operations, investigations into how the mine void may be partially backfilled and maintain a localised groundwater sink will be undertaken.

## 5.2 Closure Objectives

The broad closure objective for the Project, in line with the ANZMEC/MCA principles (Section 3.12), is to close the Project in a cost-effective and efficient manner, and leave the site safe, stable, non-polluting, and capable of supporting the agreed post-closure land uses.

More specific objectives are to:

- Meet all legal obligations for mine closure.
- Incorporate the concerns, interests and knowledge of all relevant stakeholders into mine closure planning.
- Ensure that adequate financial provision is in place for closure liabilities.
- Fully integrate mine closure planning within the LOM Plan to ensure operational efficiencies.
- Minimise the net cost of closure through ongoing mine planning to identify closure implementation efficiencies. This will include progressive rehabilitation during the operational phase and the salvage and reuse of mine infrastructure wherever practicable.
- Establish geotechnically stable/non-polluting mine landforms (particularly in reference to the WRD, TSF and open pit).
- Ensure the health and safety of mine workers and the public during suspensions of operations, decommissioning and rehabilitation.
- Minimise the spread and prevalence of weeds and feral animals.
- Maintain protection of traditional heritage and cultural values.
- Where practicable achieve self-sustaining vegetation/habitats compatible with surrounding undisturbed areas.
- Achieve maintenance free surface drainage systems.
- Minimise the visual impact of post-mining landforms.
- Relinquish the site with no outstanding legal, financial or social liability.
- Preserve access to known ore reserves or mineralised wastes with potential value.

Interim criteria by which success in achieving these objectives can be measured are presented in Section 6.2. Risks to these objectives are discussed in Section 9.2 and implementation plans by which the objectives may be achieved are presented in Section 10.

# 6. DEVELOPMENT OF COMPLETION CRITERIA

## 6.1 Principles

Completion criteria are the basis for determining whether closure objectives have been met or are likely to be met. Venturex will adopt the DMP/EPA (2015) and ANZMEC/MCA (2000) principles for development of completion criteria, which state that such criteria should be:

- Developed in consultation with key stakeholders.
- Specific enough to address the unique environmental, social and economic circumstances of each site.
- Achievable and realistic.
- Relevant to the closure objectives.
- Based on performance indicators that allow trends to be identified.
- Flexible enough to adapt to changing circumstances, while still meeting agreed objectives.
- Measured over appropriate timeframes and, where necessary, projected over a long term.
- Subject to periodic review, and where appropriate modified in light of improved knowledge, or changed circumstance.
- Developed from the commencement of project planning and refined over the life of the Project.

## 6.2 Interim Criteria

Interim completion criteria to address closure objectives for the Project are summarised in Table 4. As the Project is at a planning and pre-construction stage, the criteria are considered indicative. Where detailed criteria have not been established, reference is made to broad standards for guidance. As further information becomes available, these criteria will be refined and presented in future revisions of this MCP. In particular, Venturex recognises that it may not be realistic to aim to restore self-sustaining pre-mining ecosystems on post-mining landforms. Consequently, only broad criteria have been set for restoration of vegetation and habitats at this early stage.

**Table 4: Interim Completion Criteria for the Sulphur Springs Project**

| Regulatory Requirement | Closure Objective | Closure Strategy | Completion Criteria | Measurement |
|---|---|---|---|---|
| Safe | Inadvertent access is restricted as much as practicable to any landforms or structures that are considered unsafe | • Removal of all mine structures / buildings / foundations and machinery unless legal liability accepted by post mining landowner. | • Any remaining mine structures/buildings/ foundations to be at least 0.4m below the natural ground surface.<br>• Legal transfer of ownership of any remaining structures or buildings. | • Site inspection certification report by suitably qualified professional.<br>• Legal certification of transfer of ownership. |
| | | • Limit ability for vehicular traffic to travel over crests of any remaining pits, trenches, drains, sumps, excavations with slopes exceeding 1:2 or depths of 0.5 m.<br>• Limit ability for vehicular traffic to travel over crests of mine waste landforms higher than 5 m. | • Rehabilitated batters on mine waste landforms to be < 20 degrees and walls to excavation no steeper than 1:2 gradient if not bunded. Exceptions to be negotiated with DMIRS.<br>• Mine waste landforms in excess of 5 m vertical height to have 1.2 m crest bunds. | • Confirmation of construction of safety measures through as-constructed DTMs of all mine waste landforms. |
| | | • Construction of pit abandonment bunding around potentially geotechnically unstable landforms (300 yr time frame) to minimise inadvertent access.<br>• Permanent sealing of any opening to U/G exploration workings. | • Mining related excavation/trench/channel vertical height >1.5 m to not have a wall gradient steeper than 1:2 unless it has an effective abandonment bund.<br>• All high risk geotechnically unstable mine structures/zones to have perimeter bunding (as per DMIRS 1997 Guidelines (DOIR 1997)).<br>• Openings to any underground exploratory workings to have an engineered permanent seal comprised of concrete or metal.<br>• Any mine waste landforms located within mine pit instability zone to have competent abandonment bund to restrict vehicle access. | • Geotechnical instability zone assessment report and site inspection certification report by suitably qualified professional such as an engineer or surveyor.<br>• Site inspection certification report by suitably qualified professional such as an engineer or surveyor.<br>• As-constructed engineering drawing or photographic evidence of all mine waste landform geotechnically competent designs. |

| Regulatory Requirement | Closure Objective | Closure Strategy | Completion Criteria | Measurement |
|---|---|---|---|---|
| | | • Ensure (i) perimeter bunding on all steep side sections of mine pit lakes with lower access ramp remaining in place as an emergency exit and (ii) warnings and access restrictions. | • All high risk geotechnically unstable mine structures/zones to have perimeter bunding (as per DMIRS 1997 Guidelines (DOIR 1997)).<br>• Any post mining pit lake requires an emergency access route from the water's edge. | • Site inspection certification report by suitably qualified professional such as an engineer or surveyor. |
| | Ensure the health and safety of mine workers and the public. | • Industry OHS Regulations Standards and Procedures to be adhered to during all stages of mine closure. | • Current Australian mine industry OHS standards.<br>• *Mining Act* and Regulations (WA)<br>• *Mines Safety Inspection Act* and Regulations (WA). | • Venturex certification of all Safety Plans prior to commencement of any closure related physical works/activities. |
| Geo-physically Stable | Final mine landform designs achieves long term[1] geotechnical stability | • Identification and re-shaping of potentially geotechnically unstable mine waste landforms / embankment structures (300 yr time frame).<br>• Constructed landforms to be located outside the long term mine pit instability zone.<br>• Surface drainage control (retention, diversion and conveyance) structures to be designed to 500 yr ARI criteria with regards flood levels and flood scouring. | • All retaining dam embankments of >8m height (NRM 2002) need to comply with ANCOLD (2019) engineering design criteria.<br>• Any drainage channels located beyond the confines of the mine void to be designed to 1:500-year ARI and PMP | • Post closure mine landform locality plan indicating long term mine pit instability zone as per DMIRS 1997 Guidelines (DOIR 1997).<br>• TSF embankment stability assessment as per ANCOLD 2019 Guidelines<br>• Surface drainage diversion structures meet ANCOLD 2019 Guidelines |
| | | • Landform cover designs to be based on material geochemical characterisation, scientific | • No visual evidence of erosion gullies or tunnelling deep enough to expose underlying PAF, tailings or contaminated | • Erosion monitoring data by digital elevation model |

[1] Stability assessed over a >300 year period post closure.

| Regulatory Requirement | Closure Objective | Closure Strategy | Completion Criteria | Measurement |
|---|---|---|---|---|
| | | modelling (300 yr time frame) or site-specific trials/monitoring performance over expected regional climatic conditions.<br>• Implementation of Post Mining Land Use Management Plan | materials to wind and water erosion (erosion rate does not exceed cover design rate).<br>• Quantitative evidence of a trending transition to self-healing erosional features.<br>• Access to rehabilitated landforms limited through the use of fences, where practicable. | assessment and field verification.<br>• Site inspection records (including photographs and GIS mapping)<br>• Agreement with post closure land manager of Post Mining Land Use Management Plan. |
| | Long term stability and integrity of engineered mine landform covers. | • Effective landform drainage control measures, flow diversion and catchment flood management designs/plans.<br>• Landform cover designs to be based on material geochemical characterisation, scientific modelling (300 yr time frame) or site-specific trials/monitoring performance over expected regional climatic conditions. | • Any drainage diversion structures based on design storm for conveyance of 500-year annual recurrence interval (ARI) event and containment of 24hr probable maximum precipitation (PMP). | • Certification of adequacy of hydrological design for any diversion structure. |
| Non-Polluting | Risk of contaminated discharge or emissions from the development footprint is minimised. | • Effective encapsulation of PAF materials through appropriate design and construction.<br>• Engineered covers and effective encapsulation of any dispersive mine waste materials.<br>• Location of PAF material within the catchment of mine pit.<br>• Minimisation of sediment movement from the immediate footprint of mine landforms. Where necessary construct | • No evidence of erosion gullies or tunnelling deep enough to exposes underlying PAF, tailings or contaminated materials to wind and water erosion (erosion rate does not exceed cover design rate).<br>• As-built landform design plans plus final material characterisation certification assessment for all mine waste landforms.<br>• Mine waste landforms not to actively discharge alluvial fans or saline sediment plumes into adjacent natural drainage lines (creeks). | • Monitoring data demonstrates that erosion features are stable over multiple years. Monitoring by means of digital elevation model assessment with suitable field verification and 3rd Party certification.<br>• Remote sensing verification of no alluvial fans or saline sediment plumes actively extending beyond the immediate footprint of mine waste landforms. |

| Regulatory Requirement | Closure Objective | Closure Strategy | Completion Criteria | Measurement |
|---|---|---|---|---|
| | | sediment retention bunds along toe mine waste landforms that have potential to discharge sediment. | | |
| | | • Formulation and implementation of post-closure drainage management plan to manage seasonal seepage discharge from mine waste landforms. | • No discharge of polluted seepage waters that exceed the assimilative capacity of receiving water bodies external to the groundwater capture zone of the mine pit. | • Groundwater level monitoring of appropriately scaled monitoring network.<br>• Surface water quality monitoring.<br>• Site inspection certification report by suitably qualified professional. |
| | | • Progressive refinement of hydrological processes model based on cumulating groundwater data set. | • Hydrological impact (risk) assessment review acceptance by Competent Person.<br>• Revised, calibrated model demonstrates agreed on post closure mine pit lake water recovery trends. | • Hydrological impact (risk) assessment supported by water monitoring data and hydrological modelling to establish validity of local water resource and hydrological linkages. |
| | | • Designed covers and effective drainage (seepage) assessments.<br>• Designed covers to manage any potential dusting issue.<br>• TSF & WRD cover designed to limit rainfall infiltration | • Erosion gullies or tunnelling does not extend deep enough to expose underlying PAF, tailings or contaminated materials to on-going wind and water erosion (erosion rate does not exceed cover design rate).<br>• Minimal visible dust generated from landforms. | • Remote sensing verification with follow-up field verification.<br>• Independent verification (certification) by competent specialist. |
| | | • Operational hazardous materials management practices, such as bunding, etc. to be employed during closure process. | • All reagents and chemicals are removed from site with any residual site contamination investigated and remediated as per the *Contaminated Sites Act 2003*. | • Independent verification (certification) by competent specialist. |

| Regulatory Requirement | Closure Objective | Closure Strategy | Completion Criteria | Measurement |
|---|---|---|---|---|
| Sustainable Landuse | Rehabilitate disturbed areas to establish self-sustaining vegetation/habitats compatible with surrounding undisturbed areas | • Profiling of mine waste dumps to as best possible mirror shape of local hills and regional landscape where practicable. | • Height and shape of mine waste landforms to not exceed local natural landform geometry unless based on agreed scientific/environmental rationale. | • Photographic evidence for inclusion in final relinquishment report. |
| | | • Materials assessed as being capable of supporting vegetation growth to be used in rehabilitation (or are otherwise remediated to support growth). | • Geochemical material characterisation assessment of outer cover materials on final land surface demonstrates characteristics conducive to vegetation growth. | • Mine waste landform cover material characterisation assessments by competent person(s). |
| | | • Vegetation attributes in rehabilitated areas to have values indicative of the target post mining landuse.<br>• Surrounding physical environments with similar geology and geomorphology to constitute comparative sites for vegetation establishment performance monitoring criteria. | • Vegetation is comprised of local species based on soil physical characteristics and local comparative sites.<br>• Percentage of vegetation cover over whole of landform similar to that of surrounding area with comparable physical attributes.<br>• Vegetation demonstrates ability to become self-sustaining by having reproductive structures (e.g. flowers, fruit or seeds) and the concurrent presence of multiple life stages of plants (e.g. seedling, juvenile, mature and senescent). | • Rehabilitation performance monitoring that includes aerial photo interpretation and field verification using accepted vegetation monitoring measures and set photo points.<br>• Regrowth material fertility characterisation assessments by competent person(s). |
| | | • Weed control during closure and rehabilitation performance monitoring period. | • Effective control of Declared Weeds or Weeds of National Significance.<br>• Presence of weed (introduced) species within rehabilitated areas does not preclude growth of native species. | • Rehabilitation performance monitoring that includes aerial photo interpretation and field verification using accepted vegetation monitoring measures and set photo points. |
| Legal Compliance | Maintain compliance with all legal and | • Compile and gain understanding of legal compliance obligations to | • Closure planning and implementation is in compliance with legal obligations. | • Legal compliance audit in final relinquishment report. |

| Regulatory Requirement | Closure Objective | Closure Strategy | Completion Criteria | Measurement |
|---|---|---|---|---|
| | other requirements during the closure planning and implementation process. | ensure closure planning and actions are/facilitate compliance. | | |
| Closure Planning and Financial Provisions | Cost effective and timely closure planning and implementation | • Application of contemporary mining industry rehabilitation techniques suitable to the site conditions and constraints of the post-mining environment.<br>• Peer review of relevant engineering work to verify required standard and level of confidence. | • Certification/verification reports by suitably qualified and experienced third party peer reviewers. | • Third party peer review of relevant technical reports by suitably qualified and experienced personnel.<br>• |
| | Adequate closure provision | • Resourcing of annual update to Closure Cost Estimate.<br>• Cross-function closure planning.<br>• Resourcing of triennial MCP update.<br>• Resourcing of post-closure management and preparation of the final Relinquishment Report. | • Closure Cost Estimate meets International Financial Reporting Standards (IFRS).<br>• Venturex staff performance review KPI compliance verification.<br>• DMIRS approval of MCP.<br>• DMIRS approval of Final Relinquishment Report. | • Annual third party audit of Venturex closure cost model.<br>• Annual KPI compliance reporting.<br>• Submission of an appropriate level MCP to DMIRS.<br>• Submission of a Final Relinquishment Report.<br>• Conforms to *Corporations Act*/ AASB 137/ ASX Listing Rules requirements. |

| Regulatory Requirement | Closure Objective | Closure Strategy | Completion Criteria | Measurement |
|---|---|---|---|---|
| Stakeholder Consultation | Mine closure planning considers internal and external stakeholder interests | • Development and implementation of stakeholder consultation plan throughout mine life. | • Stakeholder Consultation Register reflects ongoing engagement with stakeholders, commensurate with interest.<br>• Stakeholder Consultation Register included in Relinquishment Report. | • Annual audit by Venturex of Sulphur Springs Stakeholder Consultation Register.<br>• Updated Stakeholder Consultation Register provided in AER. |
| Resources, Infrastructure and Heritage | Resources and infrastructure deemed potentially valuable for future utilisation is preserved and transferred to appropriate management bodies.<br>Resources and infrastructure deemed not fit for future utilisation to be recycled and/or salvaged where practicable. | • Identification, possible restoration and handover of mining infrastructure to local stakeholders.<br>• Identification of economically salvageable or recyclable parts or materials for removal offsite.<br>• Legal liability for on-going maintenance of any remaining engineering structures negotiated with formal Govt approval. | • Heritage Register included in Lease Relinquishment Report.<br>• Transfer agreements with third parties. | • Update of Heritage Register for inclusion in Lease Relinquishment Report.<br>• Legal agreements that including financial guarantees. |
| | Minimise risk of sterilisation of mineral resources | • Mine planning to reflect outcomes of ongoing exploration and geological interpretation | • All geological data/records to be made available to DMIRS at time of ML relinquishment | • Geological model progressively refined.<br>• Infrastructure placement does not compromise safe/economic access to potential resources |

# 7. COLLECTION AND ANALYSIS OF CLOSURE DATA

## 7.1 Topographical Setting

The Sulphur Springs zinc-copper mineralisation is a volcanogenic massive sulphide deposit in the central eastern terrane of the Archaean Pilbara Craton, in the northwest of WA.

The Project is in the Pilbara bioregion, which covers an area of approximately 178,500 km$^2$. This region is divided into four subregions: Chichester, Fortescue, Hamersley and Roebourne. The Project falls within the Chichester subregion, which encompasses 47% of the Pilbara bioregion.

The Chichester subregion is approximately 90,445 km$^2$ and is characterised by undulating Archaean granite and basalt plains including significant areas of basaltic ranges. This region is generally rugged and hilly with elevations up to 1,250 m above sea level, hard alkaline red soils on plains and pediments, and shallow and skeletal soils on ranges (Kendrick and McKenzie 2001).

The basalt plains host a shrub steppe of *Acacia inaequilatera* over *Triodia* spp. hummock grasslands, while tree steppes of *Eucalyptus leucophloia* occur on the ranges. Grazing of native pastures forms the dominant land use in the region with Aboriginal lands and Reserves, Unallocated Crown Land and Crown Reserves, Conservation and Mining Leases also covering significant areas within the landscape (Kendrick and McKenzie 2001). The Chichester subregion lies predominantly inland from the coast.

## 7.2 Climate

Sulphur Springs is located within the North-West (Pilbara) Climate Zone of Western Australia. The climate is arid to subtropical with an average rainfall of approximately 360 mm per annum, typically occurring during the wet season between December and March. The closest BoM weather station is Marble Bar (57 km to the east, BoM station number 004106) which has records dating back to 1901. The area experiences long hot summers and mild winters (Chart 1). Mean monthly pan evaporation significantly exceeds rainfall throughout the year, ranging from 160 mm in winter to 400 mm in summer Chart 1).

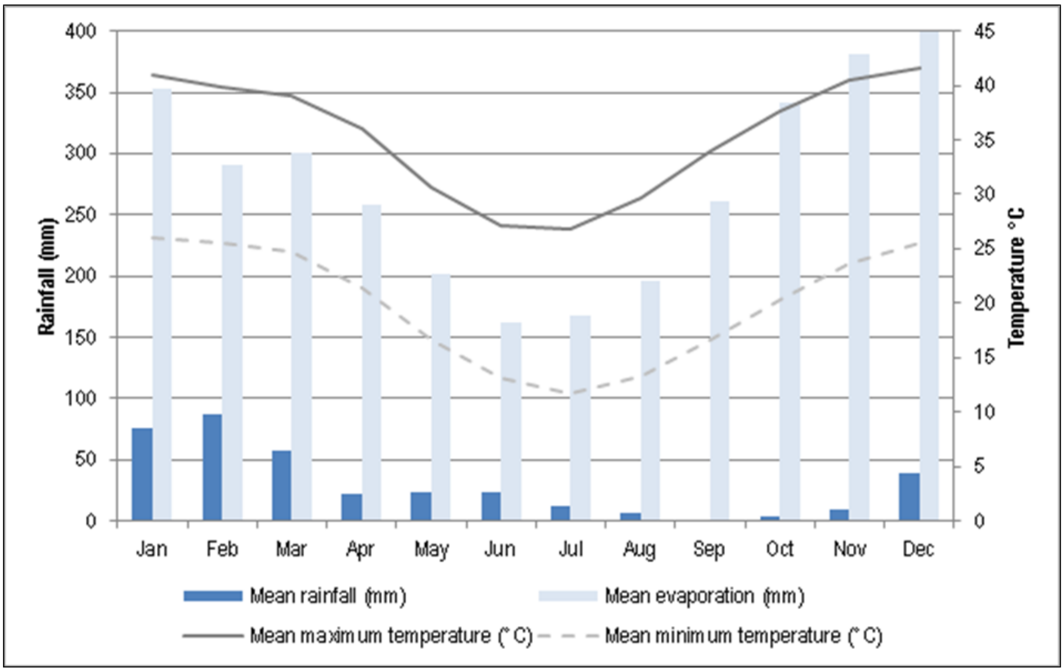



**Chart 1: Rainfall and Evaporation Data – Marble Bar Comparison 1901- 2006 (BOM 2017a)**

The Pilbara coast experiences a high frequency of cyclones with at least one severe cyclone every two years. Between 1910 and 2019 there have been 48 cyclones that have caused gale-force winds at Port Hedland with most years experiencing at least one tropical system that results in rainfall events in excess of 100 mm extending over one or more days. The 1 in 100 year 72 hour average recurrence interval (ARI) rainfall event for the Project area is 376 mm (Table 5). Between 1901 and 1996 daily rainfall has exceed 100 mm 17 times (AECOM 2020b). The maximum daily rainfall at Marble Bar, recorded on 3 February 1941 was 304 mm.

**Table 5 Annual Exceedance Probability (AEP) Rainfall Data (mm) (BOM 2017b)**

| Duration | Annual Exceedance Probability | | | | | |
|---|---|---|---|---|---|---|
| | 63.2% | 20% | 10% | 5% | 2% | 1% |
| 1 hour | 28.1 | 46.6 | 56.4 | 66.1 | 79.4 | 90.3 |
| 2 hour | 4.3 | 58.1 | 70.8 | 83.6 | 101 | 116 |
| 3 hour | 38.2 | 66 | 81.2 | 96.7 | 118 | 136 |
| 6 hour | 45.8 | 83.3 | 104 | 126 | 157 | 182 |
| 12 hour | 55.5 | 106 | 135 | 167 | 211 | 244 |
| 24 hour | 66.8 | 132 | 171 | 212 | 269 | 313 |
| 48 hour | 79.2 | 157 | 202 | 250 | 312 | 363 |
| 72 hour | 86.1 | 169 | 215 | 262 | 323 | 376 |

## 7.3 Geology

### 7.3.1 Regional Geology

The Pilbara Craton comprises Archaean and paleo-Proterozoic rocks that outcrop in the Pilbara Region of north-western Western Australia. The Craton consists of a 250,000 km$^2$ ovoid segment of terranes and basins (URS 2007a).

The northern Pilbara Craton is divided into several types of tectonic domains (Van Kranendonk *et al.* 1998). These include lithotectonic terranes, polyphase granitic complexes, individual granitic intrusions, greenstone belts (East Pilbara Terrane only) and sedimentary basins of the De Grey Supergroup (Van Kranendonk *et al.*, 2006 and URS 2007a)

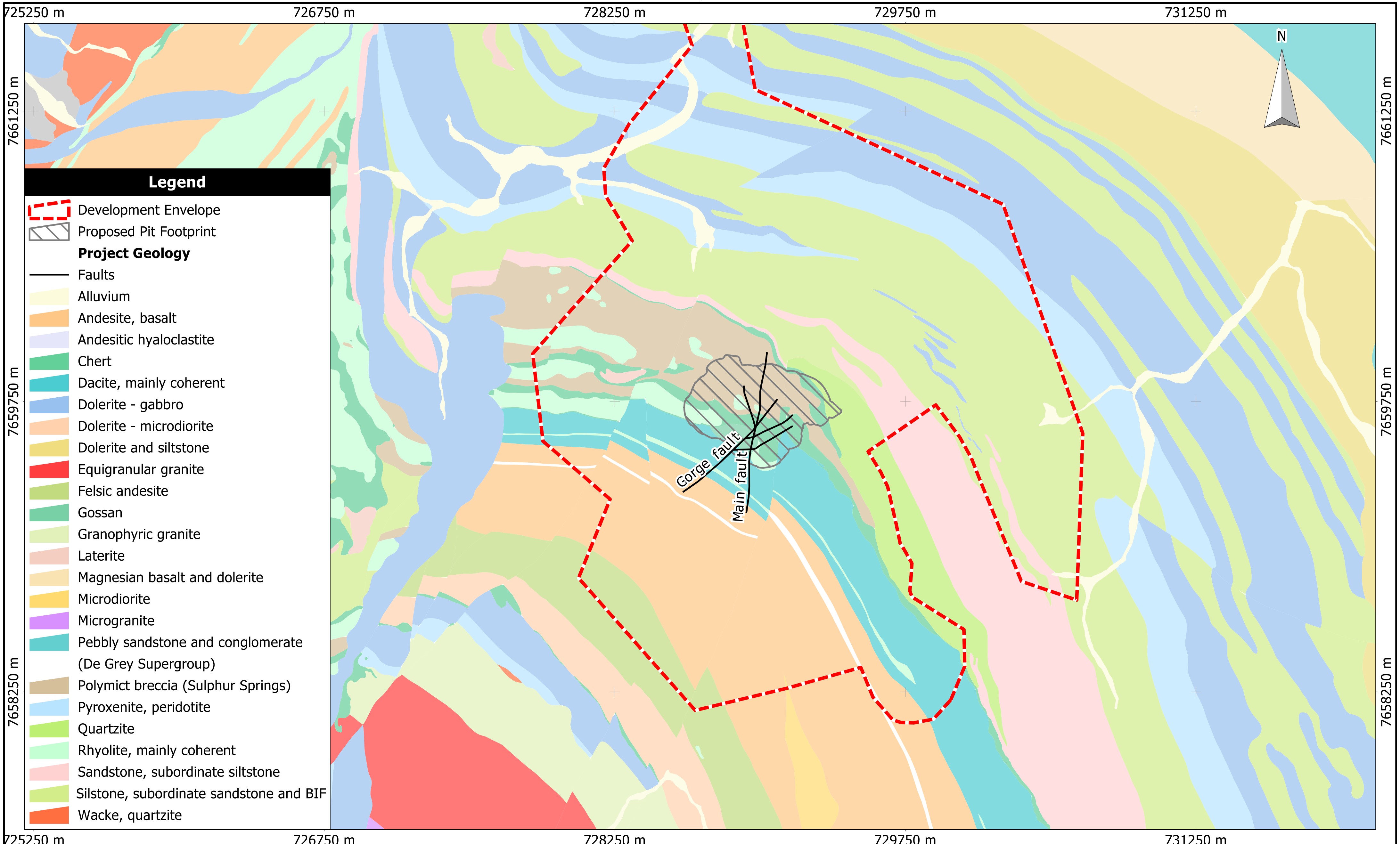
Sulphur Springs is in the East Pilbara Terrane, the oldest component of the northern Pilbara Craton. The East Pilbara Terrane is a 'dome-and-basin' granite-greenstone domain in which ovoid granites are flanked by arcuate-shaped volcano-sedimentary packages. This Terrane represents the nucleus of the Pilbara Craton, formed through a succession of mantle plumes (3,530 to 3,230 Ma) that produced a dominantly basaltic volcanic succession, known as the Pilbara Supergroup, on an older sialic basement. Granitic complexes in the East Pilbara Terrane are structural domes that are separated from one another by faults or intervening greenstone belts, or both. Each complex contains several different age components, but many of the components are common to several complexes (Van Kranendonk *et al.*, 2006).

### 7.3.2 Project Orebody Geology

The Sulphur Springs Group of the Pilbara Supergroup in the East Pilbara Terrane is host to the deposit mineralisation. North east portions of the planned mine void are expected to intercept the Soanesville Group successions, which dip 50º to 55º to the northeast. Footwall rocks are predominantly formed of dacite/rhyodacite volcanics of the Kangaroo Caves Formation (Sulphur Springs Group). Sulphide mineralisation is strongly strata bound on the contact between the footwall successions and overlying marker chert beds. Mineralisation is interpreted to occur in association with strata bound shear zones that are concordant with the shear and foliation fabric of the marker chert. Hanging wall rocks include polymict breccias and upper chert beds of the Kangaroo Caves Formation and the overlying siltstone and quartz arenite of the Corboy Formation (Soanesville Group) (URS 2007a).

Sulphide mineralisation is dominated by massive pyrite, which contains enriched horizons of sphalerite and chalcopyrite. Galena is present in minor amounts. The sphalerite rich zone lies towards the top of the massive pyrite lenses. The copper rich zone of the deposit lies towards the base of the influence of the pyrite. The pyrite lenses have a gradational contact with the barren felsic volcanics beneath.

There are seven previously modelled faults which influence the distribution of both the local stratigraphic successions and mineralisation. Three of these faults are considered major (Main, Creek and Gorge faults) and a further four are consider minor (B, C, D and F faults) (Figure 4). Both the Main and Creek faults appear to be localised in their alteration and brecciation halos, having a lower impact on local ground conditions. The Gorge fault is believed to exist as a set of fault splays, with a greater level of brecciation of the surrounding rock. This fault impacts ground conditions to a much greater extent and is pervasive across three quarters of the orebody. Intersections are often ambiguous for the four minor faults. They are localised and minor in effect and interpreted to either be related to the major faults (as splays of extensions) or to be small, older thrust faults.

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Sulphur Springs Project

**Figure 4**

**Project Geology**


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### 7.4 Local Relief and Soils

Topography in the region is characterised by numerous rocky hills and small gorges that control the flow of surface water. Elevation ranges from around 200m AHD in the alluvial flats and low hills to the north of the Project, to around 400m AHD near the proposed pit. The proposed Development Envelope encompasses a diverse landscape, where the differential weathering of basement rocks has developed sharp local changes in relief (Plate 1 and Figure 5). In this landscape, the competent lithologies tend to form topographically high areas (such as ridge lines). In contrast, zones subjected to greater geological stress may preferentially weather and erode forming the valleys (Plate 2).

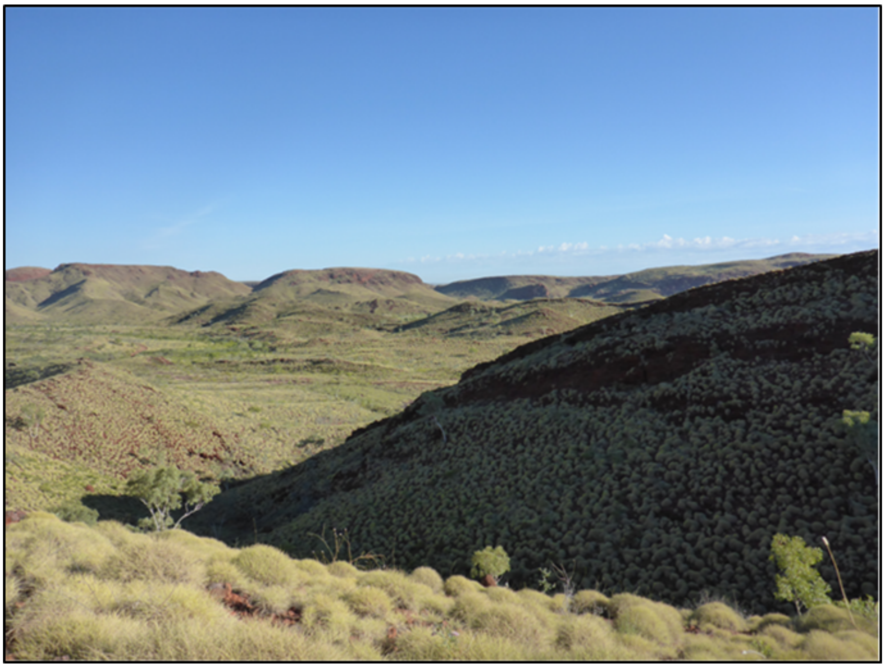


**Plate 1: Typical Topography in Mine Area**

**Plate 2: Typical Topography in Accommodation Village Area**

The Project area straddles three land systems; Boolgeeda, Capricorn and Rocklea (Figure 6). Van Vreeswyk *et al.* (2004) have defined soil types of these land systems and determined their erodibility based on geological properties and landform (Table 6).

In general, soils of the granitic terrain and within the immediate vicinity of granite hills and outcrops across the site are red shallow sands. The hills give way to broad gently sloping plains with red sandy earths, red deep sands and red loamy earths (URS 2007b). Most soil types within the hills have significant to dominant proportions of stone throughout the soil profile and often have a very stony mantle and prominent rock outcrops. Other minor soils include red shallow loams with some red shallow sands. Soils become deeper downslope. In these areas the dominant soils are stony surfaced red loamy earths. The land systems show no sign of degradation or erosion and the condition of perennial vegetation is generally good to very good (URS 2007b).

Growth medium development is localised and not extensive in the Project area. The proportion of coarse material (>2 mm) present within the soil is typically high (up to 81%), with the majority of soils assessed across the Project area having greater than 50% coarse material content (Appendix 2). Overall, Project soils are considered to be 'moderately stable' to 'stable', from an erodibility perspective, prone to hard setting, moderately transmissive with low plant-available water, variable in pH, generally non-saline and non-sodic and contain low concentrations of plant available nutrients. Soil characteristics within specific infrastructure areas are presented in Table 7. Physical and chemical characteristics of soils across the Project area are further discussed in Appendix 2.

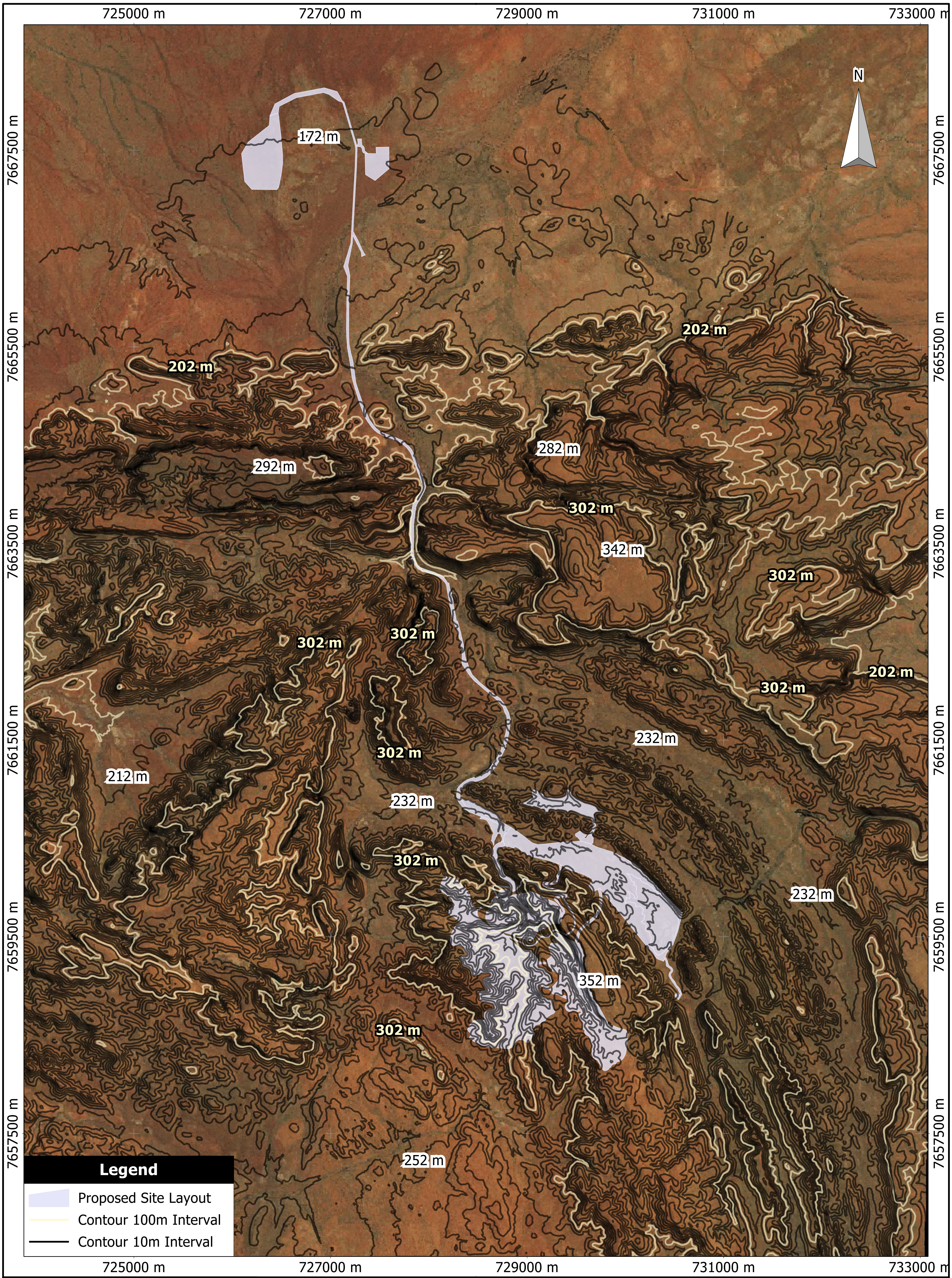
**Table 6: Land Systems of Sulphur Springs (Van Vreeswyk *et al.* 2004)**

| Land System | Project Infrastructure | Landform Types | Soil Types |
|---|---|---|---|
| Boolgeeda | • Southern half of accommodation village.<br>• Borrow pit near accommodation village.<br>• Northern section of site access road. | Gently inclined Stony Slopes and Plains. | Bare rock, red shallow earth, deep red sands, and channels with riverbed soils. |
| Capricorn | • Majority of open pit.<br>• Small northwestern portion of WRD.<br>• Processing Plant.<br>• Minor northwestern segment of TSF.<br>• Majority of site access road. | Hills and Ridges of sandstone and dolomite with steep rocky upper slopes. | Stony soils, red shallow loams, red shallow sands and riverbed soils. |
| Rocklea | • Majority of WRD.<br>• Small southern portion of open pit.<br>• Majority of TSF<br>• Northern half of accommodation village. | Basalt Hills, Plateaux, lower slopes and minor stony plains. | Stony soils and calcareous shallow loams, red shallow sandy duplex soils, shallow red/brown cracking clays, self-mulching cracking clays or the gilgai plains, channels with riverbed soils. |

**Table 7: Soil Characteristics (Outback Ecology 2013)**

| Infrastructure | Soil Physical Characteristics | Soil Chemical Characteristics | Approximate Volume of Soil Present ($m^3$) |
|---|---|---|---|
| **Boolgeeda Land System** | | | |
| • Southern half of accommodation village.<br>• Borrow pit near accommodation village.<br>• Northern section of site access road. | • Sandy loam.<br>• Prone to structural decline as a result of clay dispersion.<br>• Generally not prone to hard setting.<br>• Low to medium plant-available water, considered typical of weathered surface soils in region. | • Moderately acidic (pH 4.8) to neutral (pH 7.0).<br>• Non-saline, non-sodic.<br>• Low plant available nitrogen and phosphorus.<br>• High plant available potassium. | 3,644,816 |
| **Capricorn Land System** | | | |
| • Majority of open pit.<br>• Small northwestern portion of WRD.<br>• Minor northwest segment of TSF. | • Sandy loam.<br>• Moderately stable in structure.<br>• < 2mm fractions prone to hard setting, but this likely to be counteracted by higher content of coarse material (68%).<br>• Low to medium plant-available water, considered typical of weathered surface soils in region. | • Neutral pH (5.5).<br>• Non-saline.<br>• Non-sodic.<br>• Low plant available nitrogen and phosphorus. | Minimal recoverable growth medium due to rugged topography. |
| Processing Plant | • Sandy loam, to loamy sand to sandy clay loam to clay loam.<br>• Structural stability generally moderately stable to stable.<br>• < 2mm fractions prone to hard setting, but this likely to be counteracted by higher content of coarse material in most areas.<br>• Low to medium plant-available water, considered typical of weathered surface soils in region. | • Neutral to strongly alkaline pH (5.8 to 8.2)<br>• Generally non-saline, although some material adjacent to slopes in central area of plant identified as slightly saline.<br>• Generally non-sodic, although some material in the northwestern area of the site was sodic to highly sodic.<br>• Low plant available nitrogen and phosphorus. | 67,588 |

| Infrastructure | Soil Physical Characteristics | Soil Chemical Characteristics | Approximate Volume of Soil Present ($m^3$) |
|---|---|---|---|
| Majority of site access road | • Sandy clay.<br>• Moderately stable structure.<br>• < 2mm fractions prone to hard setting, but this likely to be counteracted by higher content of coarse material (>55%).<br>• Moderate to moderately rapid hydraulic conductivity.<br>• Low to medium plant-available water, considered typical of weathered surface soils in region. | • Neutral to moderately alkaline pH (6.6 to 7.1).<br>• Moderately saline in upstream areas close to processing plant.<br>• Non-saline in downstream areas.<br>• Non-sodic.<br>• Low plant available nitrogen and phosphorus. | 23,275 |
| **Rocklea Land System** | | | |
| • Majority of WRD.<br>• Small southern portion of open pit.<br>• Majority of TSF.<br>• Northern half of accommodation village. | • Sandy loam to sandy clay loam.<br>• Structural stability ranging from moderately stable to unstable.<br>• < 2mm fractions prone to hard setting, but this likely to be counteracted by higher content of coarse material (>60%).<br>• Low to medium plant-available water, considered typical of weathered surface soils in region. | • Neutral pH (5.6 to 6.9)<br>• Generally non-saline.<br>• Non-sodic.<br>• Low plant available nitrogen and phosphorus.<br>• High plant available potassium in some areas. | 10,000 |

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Sulphur Springs Project

**Figure 5**

**Project Area Topography**

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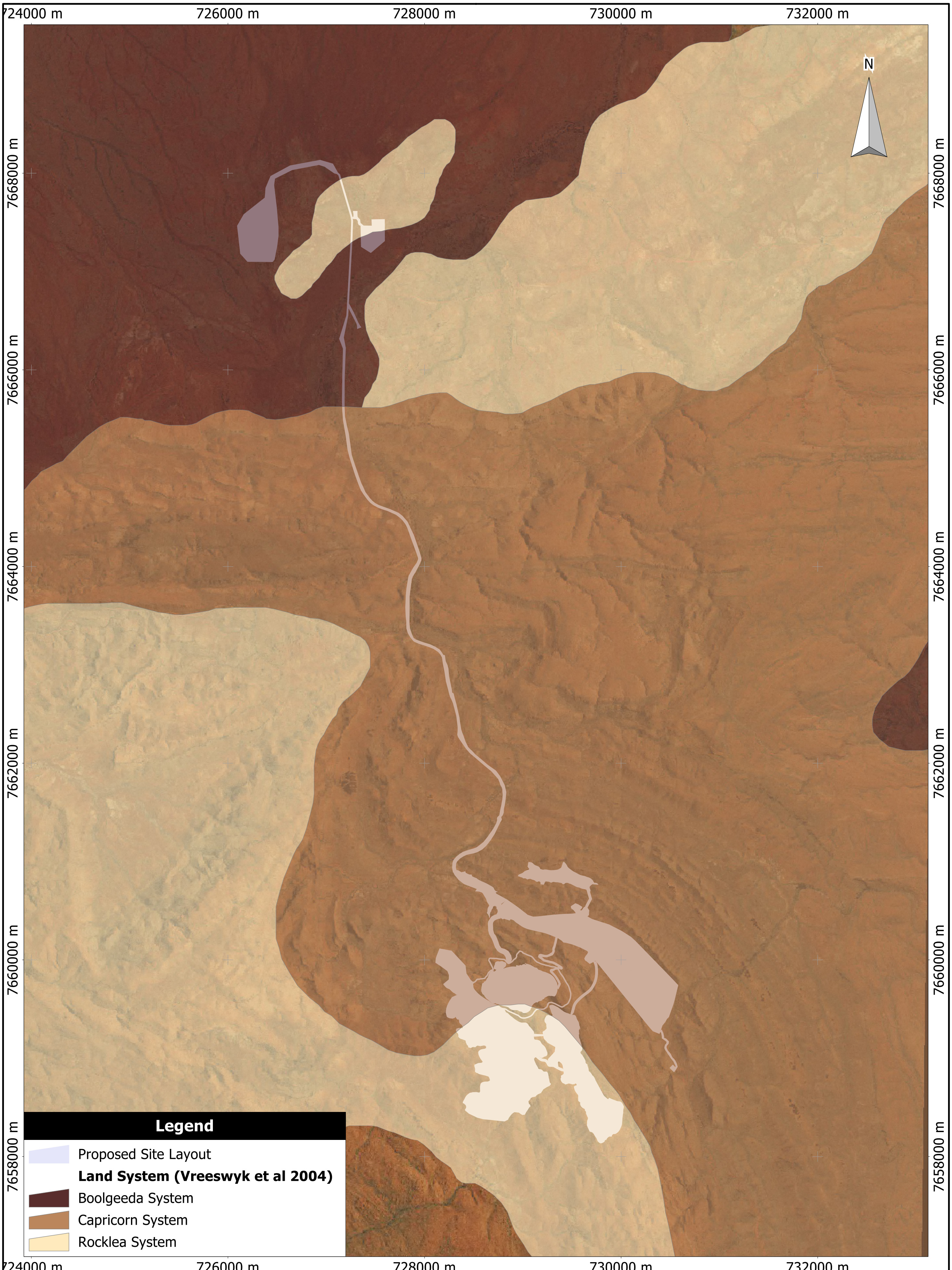
MBS ENVIRONMENTAL

W:\Venturex Resources\Sulphur Springs\Projects\2018 Mine Closure Plan\Drawings\Sulphur Springs MCP (from ERD) V6.map 24/01/2020 F5 Project Area Topography Layout

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Air Photo Date: 2012
Grid: MGA94(50)

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Venturex Limited Resources
Sulphur Springs Project

**Figure 6**

**Proposal Area Landforms**

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## 7.5 Hydrology

### 7.5.1 Regional Hydrology

Regionally, Sulphur Springs is situated on the boundary between the Shaw River catchment and the Strelley River catchment. The Shaw and Strelley Rivers are ephemeral and characteristically flow in the lower courses through extensive floodplains while upper portions traverse deep gorges. Waterholes within low-lying stretches of the drainage lines may exist for much of the year but most are dry from May to November. After heavy rains the rivers flood and often overflow their banks causing inundation of the coastal plain. Most of the rivers in the Pilbara region, including the Shaw and Strelley, have broad alluvial sands or zones of unconsolidated rock saturated with groundwater along their courses (URS 2013).

The Project area is within the Pilbara Surface Water Management Area, which encompasses the majority of the Pilbara region and is proclaimed under the *Rights in Water and Irrigation Act 1914*, administered by the DWER. The proposed mine will be located well upstream of a proclaimed water reserve (Priority 1 Drinking Water Source Area), which is located along the lower reaches of the De Grey River (AECOM 2020b)

### 7.5.2 Local Hydrology

There are three catchments within the Project area: Sulphur Springs Creek Catchment, Minnieritchie Creek Catchment and Six Mile Creek Catchment (Figure 7).

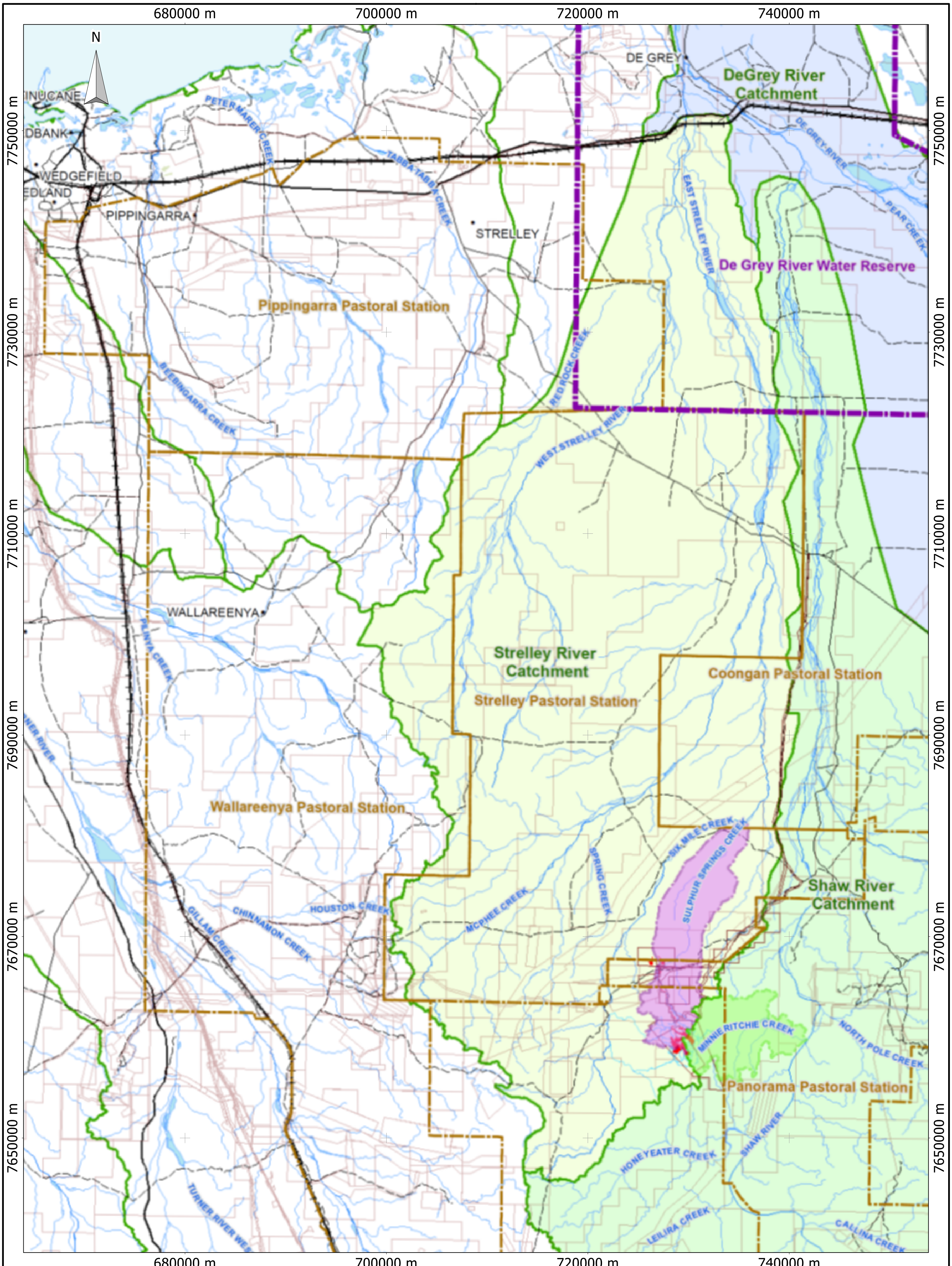
Surface water drainage varies throughout the Project. In the western portion of the mine site, surface water drains north-west through incised drainage channels and alluvial flats into Sulphur Springs Creek, which meets Six Mile Creek before merging into the Strelley River (Figure 7). Surface water flows from the eastern part of the mine site drain east into Minnieritchie Creek via numerous small creeks. Minnieritchie Creek flows eastwards into the Shaw River. In the southern portion of the mine site footprint surface water drains south towards Six Mile Creek.

Creeks and drainage channels in the Project area are typically dry for most of the year, except during the wet season and immediately following thunderstorms or tropical low pressure systems/cyclones. There are also ephemeral pools along the proposed access track and within the upper reaches of Sulphur Springs Creek and Minnieritchie Creek (AECOM 2020a). These may be present for much of the year but are generally dry from May to November. Groundwater discharge occurs in valley-floor domains and associated surface water features such as water courses, pools and springs (AECOM 2020a). Baseflows are mainly due to groundwater inflows.

Hydrological characteristics of the Project area were defined by AECOM (2020b) and a Surface Water Management Plan has been developed for the Project (AECOM 2020c). Surface water characteristics relevant to mine closure identified by AECOM (2020b) are outlined in the sections below.

The hydrology of the Project site has been modelled (AECOM 2020b) using a RORBWin Hydrological Routing Software model to simulate the hydrological characteristics of the three catchment areas potentially affected by the proposed Project. This included stream flow characterisation (perennial, episodic), estimated annual stream flow volumes, and episodic streamflow vs episodic rainfall for 2yr, 5yr, 20yr and 100yr Average Recurrence Interval (ARI) events.

Stream flow characteristics under baseline conditions are summarised in Table 8 and peak discharge rates in Table 9.

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Source: AECOM 2020
Grid: MGA94(50)
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Sulphur Springs Project

**Figure 7**

**Regional Catchments**

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**Table 8: Simulated Stream Flows at Key Locations Along the Three Creek Systems**

| Catchment | Area (ha) | Ave Annual Runoff (ML) | Event Runoff (ML) for years ARI | | | |
|---|---|---|---|---|---|---|
| | | | 2 | 5 | 20 | 100 |
| **Minnieritchie Creek** | | | | | | |
| MRC2 | 650 | 868 | 119 | 336 | 825 | 1,530 |
| MRC4 | 1,054 | 1,407 | 194 | 545 | 1,338 | 2,484 |
| | | | | | | |
| **Sulphur Springs Creek** | | | | | | |
| Upstream of mine pit a | 61 | 81 | 9 | 31 | 75 | 141 |
| Upstream of mine pit b | 51 | 67 | 9 | 30 | 74 | 140 |
| Below mine pit | 177 | 237 | 32 | 102 | 250 | 472 |
| Below process plant | 87 | 115 | 13 | 39 | 96 | 180 |
| Downstream confluence | 264 | 352 | 44 | 140 | 346 | 652 |
| | | | | | | |
| **Six Mile Creek** | | | | | | |
| Below WRD | 47 | 62 | 16 | 23 | 58 | 109 |
| SMC Pond | 1234 | 1,647 | 430 | 644 | 1,586 | 3,003 |

**Table 9: Simulated Peak Flow Rates at Key Locations Along the Three Creek Systems**

| Catchment | Peak Discharge Rates ($m^3$ per sec) for years ARI | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 5 | 20 | 100 | 500 | 1,000 |
| **Minnieritchie Creek** | | | | | | |
| MRC Pool 1 | 10.7 | 23.9 | 40.5 | 61.9 | 86.9 | 98.6 |
| MRC Pool 2 | 16.1 | 39.0 | 66.3 | 101.7 | 142.8 | 162.0 |
| | | | | | | |
| **Sulphur Springs Creek** | | | | | | |
| Upstream of mine a | 0.9 | 2.1 | 3.6 | 5.5 | 7.7 | 9.0 |
| Upstream of mine b | 0.9 | 2.1 | 3.6 | 5.5 | 7.7 | 8.8 |
| Below mine pit | 2.6 | 6.1 | 10.2 | 15.6 | 22.0 | 25.0 |
| Below process plant | 1.3 | 2.8 | 4.8 | 7.3 | 10.3 | 11.8 |
| Downstream confluence | 3.9 | 8.9 | 14.9 | 22.9 | 32.3 | 36.8 |
| | | | | | | |
| **Six Mile Creek** | | | | | | |
| Below WRD | 1.1 | 1.2 | 2.9 | 4.4 | - | - |
| SMC Pond | 27 | 46 | 81 | 126 | - | - |

#### 7.5.2.1 Minnieritchie Creek Catchment

Baseline hydrology of Minnieritchie Creek (MRC) (AECOM 2020b) includes:

- The sub-catchment area including the process plant contributes about 20% of the runoff at MRC2 and 13% at MRC4. Consequently, runoff at MRC2 is about 5 times greater and 8 times greater at MRC4.Highly variable rainfall to which the catchment responds rapidly. Consequently, stream flows reduce significantly within a short period of time after the event. Base flows are mainly due to groundwater inflow into the creek.
- The riverine environment is able to adapt to large variability, including short duration stream flow events.

#### 7.5.2.2 Sulphur Springs Catchment

Baseline hydrology of Sulphur Springs Creek (SSC) (AECOM 2020b) includes:

- The catchment area of the proposed pit is about 156 ha and comprises six sub-catchments, including the pit shell, part of the WRD and the TSF. Runoff from the upstream areas will be diverted, intercepted and taken into the process water circuit or pumped (minor volumes) from the pit to the process water circuit.
- Peak flow rates from these catchments vary greatly. The catchments have a relatively fast response to rainfall events, and stream flows are expected to reduce significantly within a short period of time. Base flows are mainly due to groundwater inflow into the creek line.

#### 7.5.2.3 Six Mile Creek Catchment

Baseline hydrology of Six Mile Creek (SMC) (AECOM 2020b) includes:

- The southern part of the footprint of the proposed waste rock dump (WRD) covers an area of approximately 47 ha in the upper reaches of the SMC catchment. The footprint stretches over sub-catchment areas that are drained by three different drainage lines. The stream flow volume downstream of the confluence of these three drainage lines is about 7 times the total estimated stream flow volume from the WRD areas combined.
- Given the WRD location at the top of the regional divide, runoff response times are very fast, but local volumes and flow durations are expected to be small.

### 7.5.3 Surface Water Quality

Sampling and analysis of surface water across the Project area has been completed by Golder Associates (2007), URS (2007a) and AECOM (2020b). Interpretation of this data indicates that pools and springs sampled in the upland areas are composed of an increasing component of water derived from recent or short residence infiltration from rainfall events (URS 2007a) (Figure 7). In the vicinity of the proposed pit, gravity (or descending) springs discharge under unconfined conditions.

Baseline water quality data in the Sulphur Springs catchment (Table 10) reflects the general water quality in the vicinity of proposed infrastructure.

Baseline water quality data indicate that metal and metalloid concentrations exceed the ANZECC (2000) Guidelines for Aquatic Ecosystems in water discharging from the proposed mine area. This is due to groundwater flow through highly mineralised zones.

Surface water quality within the Project area varies widely (AECOM 2020b). In the Sulphur Springs Catchment, perennial discharges of groundwater support surface water flows. These discharges come from mineralised bedrock with low pH and elevated concentrations of salinity, sulphate and metals/metalloids including cadmium, copper, nickel and zinc. Outside the mineralised zone, surface water generally has a close to neutral pH, low salinity and lower concentrations of metals and metalloids. Seasonal variations in concentrations of alkalinity occur as a result of evapoconcentration of solutes and biological activity in dry season pools.

**Table 10: Sulphur Springs Creek Surface Water Quality Data (AECOM 2020b)**

| Parameter | Units | Upstream | Mine Site | Downstream |
|---|---|---|---|---|
| pH | mg/L | 6.8 – 8.5 | 2.6 – 3.2 | 7.0 – 8.2 |
| Salinity (TDS) | pH units | 170 - 270 | 510 - 960 | 720 – 1,300 |
| Alkalinity as $CaCO_3$ | mg/L | 40 – 205 | <1 | 380 - 517 |
| Aluminium | mg/L | <0.01 | **2.6 – 22.2** | <0.01 |
| Cadmium | mg/L | 0.0006 – 0.0015 | **0.035 – 0.136** | <0.0001 – 0.0002 |
| Cobalt | mg/L | <0.001 | 0.053 – 0.122 | <0.001 |
| Copper | mg/L | <0.005 – **0.036** | **0.37 – 4.29** | <0.001 – 0.002 |
| Lead | mg/L | <0.001 – 0.002 | 0.006 – **1.0** | <0.001 |
| Iron | mg/L | <0.05 | 0.96 – 129.0 | <0.05 |
| Manganese | mg/L | 0.018 | 1.26 – 6.21 | 0.042 |
| Nickel | mg/L | 0.007 – **0.029** | **0.031 – 0.150** | <0.001 – 0.006 |
| Zinc | mg/L | **0.166 – 0.62** | **9.5 – 58.0** | <0.005 – 0.014 |
| Sulphate to Chloride Ratio | N/A | 0.2 – 0.8 | 4.4 – 14.5 | 0.4 – 1.7 |
| Major Ion Composition | N/A | Magnesium Chloride | Magnesium Sulphate | Magnesium Bicarbonate |

***Bold** values exceed freshwater ecosystem guidelines (95% protection – ANZECC & ARMCANZ 2000). Values for Cd, Cu, Ni, Pb and Zn compared to trigger values adjusted for hardness.*

#### 7.5.3.1 Minnieritchie Creek Catchment

The quality of surface water in the Minnieritchie Creek catchment is similar to other nearby unmineralised catchments. The quality fluctuates seasonally depending on rainfall and the concentrations of solutes that accumulate from groundwater discharge and are dispersed by runoff.

Surface water in this catchment is circum-neutral, fresh, has low concentrations of metals/metalloids and nutrients, and has a high alkalinity. The major ion chemistry is dominated by magnesium-bicarbonate because of geochemical reactions within the catchment, particularly where the baseflow is derived from groundwater that has recharged an aquifer comprising mafic rock types.

#### 7.5.3.2 Sulphur Springs Catchment

The pit will function as a hydraulic sink collecting groundwater seepage, direct rainfall on the pit area and any uncontrolled inflows from the upstream areas draining into the pit. These inflows to the pit will form a lake which will over time stabilise as evaporation balances the inflow. The final water level will reflect this balance and show a degree of seasonal variability.

Baseline surface water quality parameters for several metals along the groundwater discharge zone within the mine exceed the freshwater ecosystem guidelines (ANZECC & ARMCANZ, 2000). Baseline data upstream of the mineralised zone also have concentrations above these guidelines for copper, nickel and zinc. Downstream of the mineralised area the concentrations of all metals were below these guideline values.

Key characteristics of baseline surface water quality at Sulphur Springs Creek include:

- Compared with other catchments in the region, surface water discharging from the mine area has distinctly lower pH and alkalinity, and higher salinity, dissolved metals/metalloids and ionic proportions of sulphate. Evaporation of this water has left distinctly sulphurous residues along the creek bed.
- The catchment surrounding the mine evidently has low levels of mineralisation since surface water entering the proposed pit area has lower alkalinity and traces of several metals including copper, nickel and zinc.
- Surface water along Sulphur Springs Creek retains a hydrochemical signature from the mineralised groundwater discharges in the mine site. The ionic proportions of sulphate (dominant in the mine site) are rapidly reduced once it is mixed with water from the western arm of Sulphur Springs Creek where it becomes increasingly bicarbonate-dominant.

A recent groundwater assessment (AECOM 2020a) indicates that acidic discharges along Sulphur Springs Creek will cease once mine dewatering lowers the water table below the creek bed. As a result, the quality of surface water along Sulphur Springs Creek downstream of the mine is expected to slowly revert to a magnesium-bicarbonate type water. This change is not expected to significantly alter the alkalinity or hydrochemistry of metals / metalloids, but it will reduce the overall sulphate loadings. Eventually, once residual sulphate loadings within the catchment have been dispersed, surface water is expected to trend towards the bicarbonate-dominant water type observed in other catchments.

#### 7.5.3.3 Six Mile Creek Catchment

Surface water at site SMC1 in the Six Mile Creek Catchment is:

- Weakly alkaline, with pH ranging from 8.0 to 8.4.
- Fresh, with total dissolved solids concentrations ranging from 256 to 333 mg/L.
- High in alkalinity – 523 mg/L to 572 mg/L (as $CaCO_3$).
- Characterised by low sulphate to chloride ratios – 0.1 to 0.2.
- Generally low in concentrations of trace metals / metalloids and nutrients.
- Characterised by occasional detections of copper (0.001 to 0.004 mg/L).
- A generally magnesium-bicarbonate water type, similar to surface water and groundwater in other unmineralised catchments such as Minnieritchie Creek.
- Hydrochemically very similar to sites MRC2 and MRC4 on Minnieritchie Creek which are also unaffected by mineralisation.

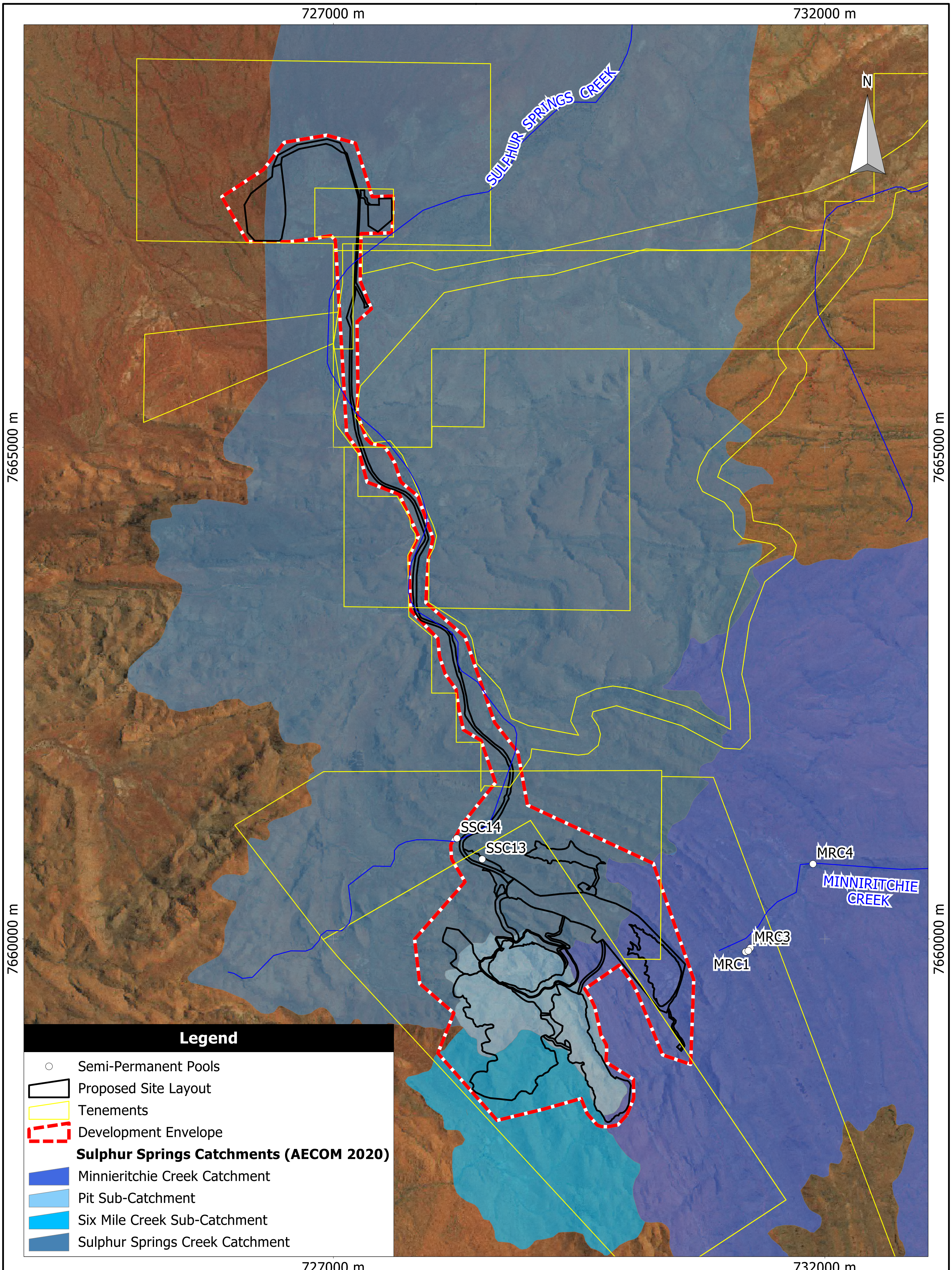


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**Figure 8**

**Project Area Sub-Catchments**

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W:\Venturex Resources\Sulphur Springs\Projects\2018 ERD\Drawings\Sulphur Springs ERD.map 28/01/2020 MCP F8 Project Area Sub-catchments Layout

## 7.6 Hydrogeology

Conceptual hydrogeology for the Sulphur Springs area has been characterised through interpretations of the Archaean geology, catchment distributions, data obtained during exploratory drilling and recent groundwater investigations (URS 2007a and AECOM 2020a).

Local geology, mineralisation and structure are major influences on hydrogeology in the Sulphur Springs mining void area. The proposed void and immediate hinterland hosts a fractured rock aquifer system that is interpreted to be closely controlled by both mineralisation lodes and occurrence of the marker chert. The local fractured rock aquifer system is interpreted to be compartmentalised, with groundwater flow strongly linked to transmissive structures.

Groundwater and surface water flow systems in the area are complex, variable and linked (AECOM 2020a). There are strong correlations with topography, geology and structure (such as faults and thrusts).

Hydrogeological characteristics at Sulphur Springs include:

- Groundwater flow and groundwater gradients that broadly reflect the local topography.
- Recharge that occurs in upland areas and groundwater discharges to valley floor domains and associated watercourses.
- Recharge areas dominate the catchment surface area. Recharge mobilises quickly down slope within a weathered bedrock aquifer.
- Groundwater discharge occurs in creeklines. The rate and extent of discharge varies seasonally. Base flows discharge perennially but are more obvious in the dry season. Groundwater discharges in the dry season result in the accumulation of precipitates of iron sulphate and silica within and immediately downstream of the mine area, as well as calcium/magnesium sulphates and carbonates elsewhere.
- Geological units and structures such as faults and thrusts influence groundwater and surface water flow systems. Groundwater flow is predominantly linked to fractures in bedrock and local geology has the potential to compartmentalise fractured rock aquifer systems and associated groundwater flow, which may influence aquifer system limits, drawdown extents and local volumes of stored groundwater that is connected to the mine.
- Most of the known fractured-rock aquifer systems are aligned with valley-floor watercourses and associated shallow water table settings.
- Groundwater levels fluctuate in response to seasonal rainfall patterns. Monitoring over the past ten years indicates the water table fluctuates seasonally by up to 5 m.
- The occurrence of pools on valley floors shows where the water table is shallow and the local aquifer systems are seasonally full.
- Water quality varies widely:
  - Within the pit footprint, solution cavities have formed through extensive oxidation of sulphide materials, resulting in groundwater that is low in pH and contains elevated concentrations of salinity, sulphate and metals/metalloids including cadmium, copper, nickel and zinc.
  - Outside the mineralised zone, surface water and groundwater are typically of near-neutral pH, low in salinity and contain lower concentrations of metals and metalloids.
- Groundwater within the orebody discharges into Sulphur Springs Creek. Groundwater and surface water quality data suggest that this has created acidic conditions and elevated metal concentrations in the creek system within the orebody zone (Plate 3). Groundwater chemistry most likely evolved through chemical equilibration with the more reactive minerals in this zone (AECOM 2020a).

Hydrogeological characteristics relevant to mine closure identified by AECOM (2020a) are outlined in the sections below.

**Plate 3: Existing Low pH Conditions in Sulphur Spring Creek**

#### 7.6.1 Groundwater Levels

Groundwater level data at Sulphur Springs were collected in June 2007, October and November 2011, August 2012, and between September 2017 and March 2018. Results suggest water level mimics topography, indicating groundwater flow is compartmentalised by bedrock beneath ridges, which is resistant to weathering and weathered and fractured bedrock on low-lying areas along drainage lines.

Water levels in the proposed mining area vary from 304 metres Australian Height Datum (mAHD) to 240 mAHD. The steepest gradients are present along the slopes of valleys, and lowest along valley floors. Water levels in surrounding areas vary and were recorded at:

- Eastern tributaries in Sulphur Springs Catchment: 211 mAHD to 259 mAHD.
- Western tributaries in Sulphur Springs Catchment: 226 mAHD to 261 mAHD.
- Minnieritchie Creek Catchment: 230 mAHD to 248 mAHD.
- Six Mile Catchment: 257 mAHD to 279 mAHD.

Generally, larger fluctuations in water level occur in elevated sections of the catchment. These fluctuations are associated with groundwater recharge areas. Smaller fluctuations occur in low-lying areas where groundwater discharges.

### 7.6.2 Groundwater Quality

Groundwater quality data at Sulphur Springs is indicative of a stratified aquifer system, with poor quality groundwater associated with the orebody and the country rock hosting fewer saline resources (URS 2007a).

The Project area and surrounds contains three domains of groundwater quality that include: the catchment encompassing the mining area (mine catchment), the mineralised area where ore body is located (Mineralised Area), and groundwater outside the mineralised area. A summary of groundwater quality is provided in Table 11. Groundwater within the orebody zone is known to discharge into Sulphur Springs Creek. Groundwater and surface water quality data indicate this mechanism has led to the development of acidic conditions and elevated metal concentrations in the creek system within the orebody zone. As a result, groundwater within the orebody zone exhibits a unique chemical signature compared to groundwater elsewhere in the system (Table 11).

Groundwater type and quality varies across the Project area. The dominant groundwater type is magnesium bicarbonate ($MgHCO_3$), with minor magnesium – sodium chloride (Mg-NaCl) and magnesium sulphate ($MgSO_4$) groundwaters in upland areas (URS 2007a and AECOM 2020a). Typically, recharged groundwater exhibits high concentrations of bicarbonate that are consumed as it flows through the aquifer (AECOM 2020a). In upland areas these reactions mobilise ions including sodium, calcium and magnesium from weathered bedrock.

Within the mineralised area, alkalinity is consumed by oxidation of sulphide minerals (AECOM 2020a). This results in increased acidity and low pH, and the release of sulphate and trace metals. Elevated concentrations of trace metals in the mineralised area include: aluminium (up to 16mg/L), cadmium (up to 0.46 mg/L), cobalt (up to 0.30 mg/L), copper (up to 3.02 mg/L), lead (up to 3.23 mg/L), iron (up to 2,730 mg/L), manganese (up to 38.2 mg/L), nickel (0.495 mg/L) and zinc (up to 218 mg/L). Mass removal of minerals has created cavity structures along geological structures, particularly where geological structures converge.

Groundwater within the orebody zone discharges to Sulphur Springs Creek. Groundwater and surface water quality data indicate this mechanism has led to the development of acidic conditions and elevated metal concentrations in the creek system within the orebody zone. As a result, groundwater within the orebody zone exhibits a unique chemical signature compared to groundwater elsewhere in the system.

**Table 11: Groundwater Quality Data (AECOM 2020a)**

| Parameter | Units | Mine Catchment | Mineralised Area |
|---|---|---|---|
| pH | pH units | 6.1 – 8.4 | 2.8 – 6.9 |
| TDS | mg/L | 172 - 370 | 388 – 1,900 |
| Alkalinity | mg/L | 97 - 223 | <1 - 91 |
| Sulphate to Chloride ratio | N/A | 0.4 – 3.4 | Up to 117 |
| Major Ion Composition | N/A | Calcium or magnesium bicarbonate | Magnesium or sodium sulphate |
| **Metals and Metalloids** | | | |
| Copper | mg/L | <0.001 | <0.006 |
| Nickel | mg/L | <0.002 | 0.119 – 0.014 |
| Zinc | mg/L | <0.005 | 0.039 – 0.045 |
| Selenium | mg/L | <0.01 | <0.01 |

## 7.7 Flora and Vegetation

### 7.7.1 Regional

The Sulphur Springs Project is located within the Chichester Interim Biogeographic Regionalisation of Australia (IBRA) subregion of the Pilbara IBRA region. The subregion is characterised by undulating Archaean granite and basalt plains including basaltic ranges. The plains support shrub steppe of *Acacia inaequilatera* over *Triodia wiseana* hummock grasslands, while tree steppes of *Eucalyptus leucophloia* occur on the ranges (Kendrick and McKenzie 2001). The Project area is also located within the Fortescue Botanical District of the Eremaean Botanical Province biogeographical region as described by Beard (1990).

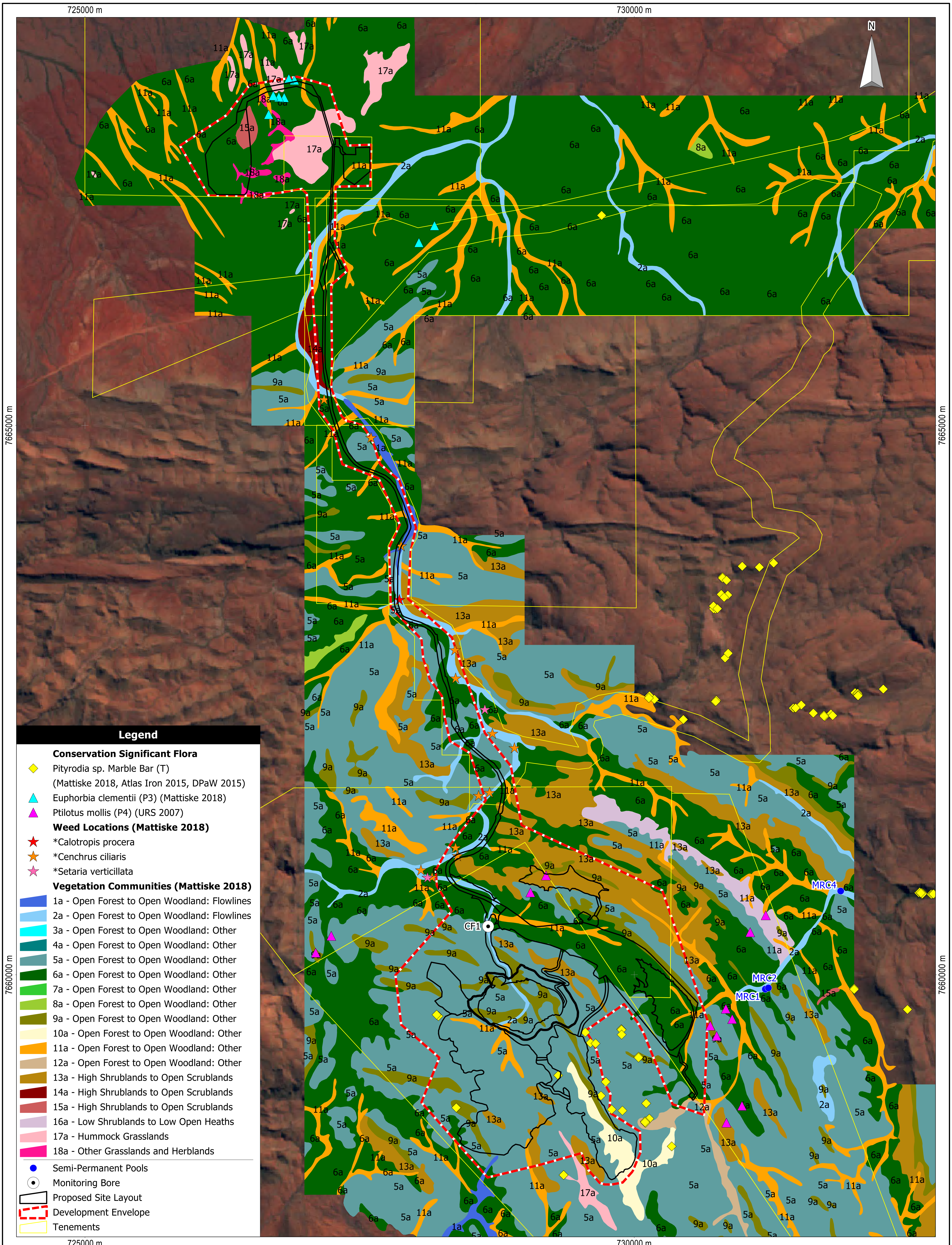
### 7.7.2 Project Area

A number of vegetation and flora surveys have been undertaken for the Project and broader regional area. Results from these surveys were compiled by Mattiske (2018). The desktop assessment, together with additional flora and vegetation surveys conducted by Mattiske (2018), cover a total survey area of 12,520 ha. Mattiske (2018) reported a total of 360 vascular plant taxa, representative of 139 genera and 48 families, within the wider Project area. The most common families recorded included Fabaceae (77 taxa), Poaceae (60 taxa) and Malvaceae (37 taxa).

No Threatened Ecological Communities (TECs) as defined by the *EPBC Act* (Commonwealth) or the *BC Act* occur in the Project area. No Priority Ecological Communities (PECs) as listed by DBCA (2018) occur within the Project area.

Trudgen *et al*. (2002) and Trudgen (2006) identified *Pityrodia* sp. Panorama and *Themeda* sp. Panorama as potentially new flora species within the Project area. Ecologia (2012) confirmed that *Pityrodia* sp. Panorama is *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4), now listed as Endangered under the *BC Act* and the *EPBC Act*. *Themeda* sp. Panorama is no longer a species of importance (email correspondence from Stephen van Leeuwen (DPaW, now DBCA) on 11 April 2016). The Sulphur Springs Project has been designed to avoid all known *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) plants. The final design for the TSF footprint encroaches within 50 m of eight plants.

A total of 18 vegetation communities in six vegetation formations were noted within the general Project area (Figure 9). Clearing is proposed in 13 vegetation communities with losses of the total area mapped locally less than 2.5%. Mattiske (2018) inferred that both vegetation communities 1a and 2a had a moderate likelihood of being a GDE. The total mapped area of vegetation communities 1a and 2a within the Development Envelope totals 32.7 ha which represents 5.1% of the total area mapped for these communities. All other vegetation communities were rated with a low GDE probability (Mattiske 2018).

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|---|---|---|---|
| Scale: 1:30000<br>Original Size: A3<br>Image source: Copernicus Sentinel Data 2018<br>Grid: MGA94(50)<br>0 1 km | Venturex Resources Limited<br>Sulphur Springs Project | **Figure 9**<br>**Sulphur Springs Vegetation Communities** | Martinick Bosch Sell Pty Ltd<br>4 Cook St<br>West Perth WA 6005<br>Ph: (08) 9226 3166<br>Fax: (08) 9226 3177<br>info@mbsenvironmental.com.au<br>www.mbsenvironmental.com.au<br>MBS ENVIRONMENTAL |

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## 7.8 Fauna

### 7.8.1 Terrestrial Fauna and Habitat

A desktop survey identified up to 268 terrestrial vertebrate fauna species potentially occurring within the greater study area surrounding the Project, including 40 mammals, 125 birds, 94 reptiles, and 9 amphibian species (KEC 2017). The majority of these species form assemblages that occur across a variety of the habitats present within and surrounding the footprint. These assemblages are also similar to those found in the surrounding landscape.

Several conservation significant fauna species were recorded within the Development Envelope:

- Northern Quoll (*Dasyurus hallucatus*).
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*).
- Long-tailed Dunnart (*Sminthopsis longicaudata*).
- Western Pebble-mound Mouse (*Pseudomys chapmani*).
- Rainbow Bee-eater (*Merops ornatus*).

Conservation significant species recorded from the wider study area include:

- Ghost Bat (*Macroderma gigas*).
- Spectacled Hare-Wallaby (*Lagorchestes conspicillatus*).
- Brush-tailed Mulgara (*Dasycercus blythi*).
- Pilbara Olive Python (*Liasis olivaceus barroni*)

Five broad fauna habitats were identified in the Project area. Identification of these habitats was based on location, landform, substrate, vegetation community, degree of disturbance (e.g. mining and fire) and the type of habitat that they offer (Outback Ecology 2012a). These habitats are:

- Spinifex Stony Plains.
- Rocky Foothills.
- Scree Slopes.
- Drainage Lines.
- Rocky Ridges and Gorges.

An additional two fauna habitats of limited extent were identified:

- Rubble/Boulder Piles.
- Ficus Groves.

All habitat types identified are considered typical of the Pilbara bioregion. They are varied in their potential to support vertebrate assemblages and conservation significant fauna species. Of the habitat types observed, Spinifex Stony Plains, Rocky Foothills and Scree Slopes are considered widespread throughout the landscape. Table 12 shows fauna habitats within the Project footprint. Rocky Ridges and Gorges is a relatively uncommon habitat within the broader landscape (Outback Ecology 2012a). This fauna habitat type is comprised specifically of those hills featuring outcropping ironstone formations, fallen boulders, caves, overhangs and crevices (Outback Ecology 2012a). The Rocky Ridges and Gorges habitat was found to provide a number of important habitat characteristics required by several conservation significant species including the Northern Quoll (*Dasyurus hallucatus*), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*), Pilbara Olive Python (*Liasis olivaceus barroni*) and Ghost Bat (*Macroderma gigas*).

**Table 12: Fauna Habitats of the Sulphur Springs Project Area**

| Habitat | Regional Context | Total Mapped Area (ha) | Area Within Project Footprint | |
|---|---|---|---|---|
| | | | (ha) | % of Total Mapped |
| Spinifex Stony Plains | Widespread throughout the surrounding landscape.<br>Well represented in the region. | 3,064.2 | 38.8 | 1.3 |
| Rocky Foothills | Widespread throughout the surrounding landscape.<br>Well represented in the region. | 2,487.3 | 160.4 | 6.4 |
| Scree Slopes | Widespread throughout the surrounding landscape.<br>Well represented in the region. | 1,042.0 | 70.0 | 6.7 |
| Drainage Lines | Limited in the surrounding landscape but well connected.<br>Well represented in the region. | 215.2 | 4.7 | 2.2 |
| Rocky Ridges and Gorges | Limited in the surrounding landscape but well connected.<br>Not well represented in the region. | 210.7 | 39.7 | 18.8 |
| Rubble/Boulder Piles | Limited in the surrounding landscape. | 13.1 | 0.1 | 0.9 |
| Ficus Grove | Limited in the surrounding landscape. | <0.1 | <0.1 | 72.8 |

### 7.8.2 Subterranean Fauna

The most recent desktop study undertaken for the Project area (Bennelongia 2018) reviewed and consolidated findings of previous site-based and regional subterranean fauna surveys to provide a regional context for subterranean fauna habitat in the Project area. The study also assessed the likely occurrence of subterranean fauna habitat in the vicinity of Project elements.

Stygofauna were collected from both deep and shallow groundwater habitats. The deep groundwater habitats comprised fractured-rock aquifers. Shallow groundwater habitats included alluvium and calcrete, and the hyporheic (porous interstitial) zone of springs (e.g. Creek Spring in Sulphur Springs Creek) (Subterranean Ecology 2007).

Stygofauna comprised representatives of the major common groundwater taxa known in the Pilbara, including Crustacea (amphipods, copepods, ostracods, and isopods), Acariformes (aquatic mites), Nematoda (roundworms) and Oligochaeta (earthworms). More than 1,161 individual specimens were retrieved from samples, with approximately 957 individuals identified to the level of species or the lowest taxonomic rank possible (Subterranean Ecology 2007).

Twenty seven species were identified, of which 24 were found within the zone of influence of mine dewatering and water supply drawdown. Of these 24 taxa, 20 have distributions recorded outside the zone of influence, either at a local scale or further downstream in the catchments of the Shaw and East Strelley Rivers, and/or regional scale of the Pilbara (Subterranean Ecology 2007).

The four taxa not collected or otherwise recorded from outside the zone of influence were two species of Oligochaeta and two species of Nematoda. Groundwater Oligochaeta generally display widespread distributions. The taxonomy and distribution of Nematoda is poorly defined, however the collected taxa are considered likely to display similar distribution patterns to the other taxa collected during the survey.

One species of cockroach (Blattodea sp. 1) collected during surveys displayed troglomorphic characteristics. This species was found in regolith habitats outside the expected zone of influence of the proposed mine within regional areas such as Kangaroo Caves and Bernts deposits and behind the Outokumpu Camp areas. The presence of this species outside the zone of influence, combined with the extensive and continuous regolith habitat it probably inhabits means this species is of no further conservation significance for the Sulphur Springs deposit area.

#### 7.8.3 Short Range Endemics

Short Range Endemic (SRE) surveys identified four species considered to be potential SRE species, namely *Antichiropus* 'DIP005' (Millipede), *Antichiropus* 'DIP034' (Millipede), *Buddelundia* sp. 11 (Slater) and *Feaella* 'PSE007' (Pseudoscorpion) (Outback Ecology 2012b and Biota 2007).

*Antichiropus* 'DIP005', *Antichiropus* 'DIP034' and *Buddelundia* sp. 11 are all known to have a distribution which extends outside of the footprint of the Project, both in a local and regional context. Consequently, it was determined by Outback Ecology (2012b) that the Project is unlikely to pose a long term conservation risk to any of these species.

Further taxonomic and genetic work is currently in process to determine the status of *Feaella* 'PSE007'. The Project will not impact the collection location of this species.

### 7.9 Geochemical Characterisation of Waste Materials

#### 7.9.1 Waste Rock

Geochemical studies have been conducted on over 2,300 samples representing waste rock lithologies likely to be encountered during development and operation of the Project (Table 13). The high number of samples and relevant lithologies assessed and application of both static and kinetic test methodologies means the characteristics of waste materials for the Project area are well understood.

**Table 13: Waste Rock Geochemical Characterisation Studies**

| Year | Author | Study Details |
|---|---|---|
| 2007 | URS | Static and kinetic testing on 3 samples collected across the profile of the proposed 2007 pit. |
| 2008 | Lutherborrow | Sulphur analysis on 2,248 drill core samples from 118 drill holes, collected across the profile of the proposed 2007 pit. |
| 2008 | RGS | Static testing on 60 samples collected across the profile of the proposed 2007 pit and kinetic testing of six composite samples prepared from this sample set. Kinetic leach column tests were monitored over a period of five months. |
| 2012 | GCA | Static testing on 17 waste rock samples collected from deeper within the deposit profile. These samples are considered to be representative of underground waste material. |
| 2018 | MBS | Review of previous waste rock characterisation studies, identification of information gaps and static testing on 35 additional waste rock samples to fill all information gaps relevant to the Proposal. |

Results of geochemical analysis indicated the following (Table 14):

- Hanging wall waste rock: This material occurs as a sequence of sedimentary lithologies comprising mainly sandstone, siltstone, polymictic breccia and chert and is expected to contribute more than 80% of open pit waste rock. The upper 30 metres of the hanging wall is highly weathered and expected to provide significant volumes of NAF, non-saline waste rock. Acid formation potential from weathered and fresh hanging wall waste cannot be accurately predicted by lithology alone. A more comprehensive approach utilising existing data for lithology, degree of weathering and total sulphur concentration has been proposed.

- Footwall waste rock: This material is comprised predominantly of dacite/rhyodacite volcanics of the Kangaroo Caves Formation (Sulphur Springs Group). These lithologies contain moderate to very high concentrations of sulphide minerals. In combination with elevated sulphur concentrations and typically low acid neutralising capacity (ANC), most of the footwall waste rock is classified as potentially acid forming – high capacity (PAF-HC). Leachate from these freshly mined materials is predicted to be moderately acidic and contain slightly elevated concentrations of copper, lead, ferrous iron and zinc, with fresh to slightly brackish salinity. Kinetic leach column studies (RGS 2008) indicate that the sulphide minerals are very reactive when exposed to air and water and are predicted to produce highly acidic, metalliferous and saline seepage within several months of exposure.

Data from these studies was used to extrapolate across the open pit profile to provide an estimate for the relative volumes of PAF and NAF waste rock to be mined (Table 14, Entech 2018).

**Table 14: Pit Waste Rock (Entech 2018)**

| Material Type | Waste (Mt) | Proportion of Waste (%) |
|---|---|---|
| PAF | 8.1 | 19.6 |
| NAF | 33.2 | 80.4 |
| **Total** | **41.3** | **100** |

### 7.9.2 Tailings

Geochemical characterisation studies on simulated tailings samples produced during bench-scale metallurgical investigations for Sulphur Springs ore are summarised in Table 15.

**Table 15: Summary of Geochemical Studies on Sulphur Springs Tailings**

<table>
<tr><th>Author</th><th>Year</th><th>Tailings Sample Details</th><th>Study</th><th>Testwork</th></tr>
<tr><td>Roger Townend and Associates</td><td>2002</td><td rowspan="2">Tailings produced during metallurgical testwork on Sulphur Springs ore using conventional sulphide flotation, producing copper concentrate, zinc concentrate and final tailings slurry. Tailings sample considered analogous to material to be generated by current proposed Project.</td><td>Mineralogical examination</td><td rowspan="2">Static (acid-base testwork) and multi-element analysis on solids and supernatant.</td></tr>
<tr><td>Graeme Campbell and Associates (GCA)</td><td>2002</td><td>Geochemical assessment, including static (acid-base testwork) and multi-element analysis on solids and supernatant.</td></tr>
<tr><td>URS</td><td>2007</td><td>A bulk tailings sample generated during metallurgical testwork on Sulphur Springs ore. Testwork utilised conventional sulphide flotation producing copper concentrate, zinc concentrate and final tailings slurry and tailings sample is considered analogous to material to be generated by current proposed Project.</td><td>Geochemical assessment of tailings.</td><td>Static (acid-base testwork) and multi-element analysis on solids and supernatant.<br><br>Kinetic testwork (saturated and unsaturated conditions) for 159 days of leaching.</td></tr>
</table>

| Author | Year | Tailings Sample Details | Study | Testwork |
|---|---|---|---|---|
| GCA | 2011 | N/A | Literature Review and Generic Discussion to Facilitate Conceptual Planning for Process Tailings Management. | |
| KP | 2018 | Two bulk tailings slurry samples generated from 2018 metallurgical testwork | Geochemical assessment | Static (acid-base testwork) and multi-element analysis on solids and supernatant. |
| MBS Environmental | 2020 | N/A | Desktop Review of Previous Geochemical Studies for Sulphur Springs Tailings Samples | |

Assessment results indicate:

- Both the static and kinetic geochemical studies (GCA 2002, URS 2007) determined that tailings samples are classified as Potentially Acid Forming – High Capacity (PAF-HC), with low acid neutralising capacity. Samples contained high total sulphur concentrations (26 to 28%), mostly in the sulphide form and therefore capable of generating acidity.
- Initial supernatant generated from tailings was pH neutral, with selenium the only element to exceed the ANZECC 2000 Guidelines for Fresh and Marine Water Quality (0.32 mg/L versus a guideline of 0.02 mg/L).
- Tailings leachate is likely to become acidic and highly saline following a relatively short period of exposure to oxidising conditions (order of weeks). Concentrations of soluble aluminium, antimony, arsenic, cadmium, cobalt, copper, nickel, lead, selenium, zinc and sulphate are expected to exceed ANZECC 2000 Guidelines for Livestock Drinking Water Quality under these conditions.
- Kinetic leaching test data demonstrated that mercury, chromium and lead, although enriched in the tailings samples, were not significantly leached following oxidation.
- There is currently no data available to adequately characterise tailings pore-water geochemistry. This is normally assessed at a solid: solution ratio of 1:2 in order to evaluate contaminant solubility. Whilst such analyses have not been performed, kinetic leach data generated during the URS 2007 study, at a solid:solution ratio of approximately 1:10, is considered to be more representative and informative for field conditions. Static leach tests on fresh tailings at different solid:solution ratios do not reflect the potential for slight-to-moderate oxidation and resultant concentrations are often solubility-limited (MBS 2020).
- Tailings seepage source terms were characterised, based on tailings supernatant fluid composition. Although some oxidation of exposed tailings beaches may result in surface tailings porewater compositions similar to that predicted by unsaturated kinetic column tests, most of the soluble oxidation productions will return to the decant pond following high rainfall events, from where acidic constituents will be neutralised by alkali addition when the decant return water is recycled through the processing plant. Predicted base case concentrations are shown in Table 16.
- In line with the AMIRA ARD Test Handbook (AMIRA 2002), the kinetic leaching studies conducted to date have used deionised water as the standard leaching solution, as opposed to on-site water. Use of site-water for static leaches is not common practice due to the following:

- Background concentrations of metals will vary with sampling location and season. For example, it is noted from baseline monitoring data (URS 2007) that copper, which is naturally enriched in site groundwater, can vary in concentration from 0.002 to 3.0 mg/L.
- Interferences or higher limits of laboratory reporting if site water has high salinity.

**Table 16: Predicted TSF Seepage Quality**

| Constituent | Units | Expected Case Tailings Seepage Quality |
|---|---|---|
| pH | pH units | 7.34 |
| TDS | mg/L | 1,800 |
| Bicarbonate | mg $HCO_3$/L | 50 |
| Aluminium | mg/L | <0.01 |
| Arsenic | mg/L | 0.005 |
| Calcium | mg/L | 227 |
| Cadmium | mg/L | 0.005 |
| Chloride | mg/L | 140 |
| Cobalt | mg/L | 0.012 |
| Chromium | mg/L | <0.01 |
| Copper | mg/L | 0.02 |
| Iron | mg/L | 0.34 |
| Mercury | mg/L | 0.0003 |
| Potassium | mg/L | 16 |
| Magnesium | mg/L | 37 |
| Manganese | mg/L | 6.5 |
| Sodium | mg/L | 182 |
| Nickel | mg/L | 0.22 |
| Lead | mg/L | 0.02 |
| Antimony | mg/L | 0.006 |
| Selenium | mg/L | 0.2 |
| Sulphate | mg/L | 782 |
| Zinc | mg/L | 1.1 |

## 7.10 Social Surroundings

### 7.10.1 Social Setting

The closest major regional centre to the Project is Port Hedland, 144 km to the north west. The population of Port Hedland is approximately 15,000 people and the main economic drivers of the region are commercial fishing and the minerals and energy industries (REMPLAN 2017).

The Project is in the Shire of East Pilbara which has a population of 7,160. Marble Bar is the nearest regional town, 57 km to the east. With a population of around 200, Marble Bar has a police station, primary school, hospital, accommodation, airstrip and pool facilities. The area surrounding the Project is sparsely populated and the closest homestead, the Panorama Station homestead, is 26 km north east of the processing plant.

### 7.10.2 Aboriginal Heritage

The Project is in an area of determined Native Title held by the Nyamal people. A Mining Deed was executed on 3 November 2006 with the Nyamal people and provides for regular consultation and participation in the provision of cultural awareness training, site clearances, direct employment and provision of contract services to the Project. The agreement also includes payment of a net smelter royalty to the Nyamal people

One registered Aboriginal Heritage Site (site 6046) is outside of the proposed disturbance area. Five heritage surveys undertaken within the Project area identified seven cultural heritage sites of significance. These sites are within the Development Envelope, outside of the proposed disturbance footprint and will not be impacted (Figure 10). By agreement with the Nyamal People Venturex has committed to implementing a 30 metre exclusion zone surrounding each site.

### 7.10.3 Other Heritage Sites

No European heritage sites have been identified in the Project area.

No landforms within Project tenements are listed on the Western Australian Geoheritage Sites database. The large number of baseline surveys conducted across the site (including heritage and ethnographic studies), have not identified any landforms within Project tenements that could be considered rare at a local, regional or national level.

The Strelley Pool (Place No. 04446) is located approximately 7.2 km west of the Project and consists of gorges and stromatolites. The site is listed on the Heritage Council of Western Australia database of heritage places, is classified as a landscape site by the National Trust and was an indicative place under the now archived Register of the National Estate. Geoheritage sites located within 50 km of the Project tenements are summarised in Table 17 and displayed in Figure 11.

**Table 17: Geoheritage Sites**

| Name | Description | Approx. Distance from Project |
|---|---|---|
| Trendall | Archean stromatolites; Diverse assemblage of stromatolites and sedimentary facies preserved in carbonate rocks of the 3426-3350 Ma Strelley Pool Formation. Fossils discovered at this site in 1999. | 6 km southeast |
| Strelley Pool | Archean stromatolites within the Strelley Pool Formation (3426-3350 Ma); laminated grey and white chert with minor chemical and silicified siliclastic rocks. | 7.2 km west |
| Awramik (North Pole Microfossils) | Archean microfossils. | 11 km west |
| Buick (North Pole Stromatolites) | Archean stromatolites. | 13 km east |
| Lowe (Strelley West) | Archean stromatolites. | 16 km west |
| Black Range | Archean (c. 2772 Ma) 70 km long mafic dyke - feeder to Mount Roe Basalt; Dyke geomorphology. | 42 km southeast |
| Schopf (Chinaman Creek - Apex Basalt chert) | Archean microfossils | 46 km east |
| Marble Bar & Chinaman Pool | Volaniclastic breccia and conglomerate result from ancient volcanic explosion; Pillow basalts in mafic rocks evidence of subaqueous extrusion; Red and white banded jasper (Marble Bar Chert Member) sea floor sedimentation 3460 million years ago. | 47 km east |

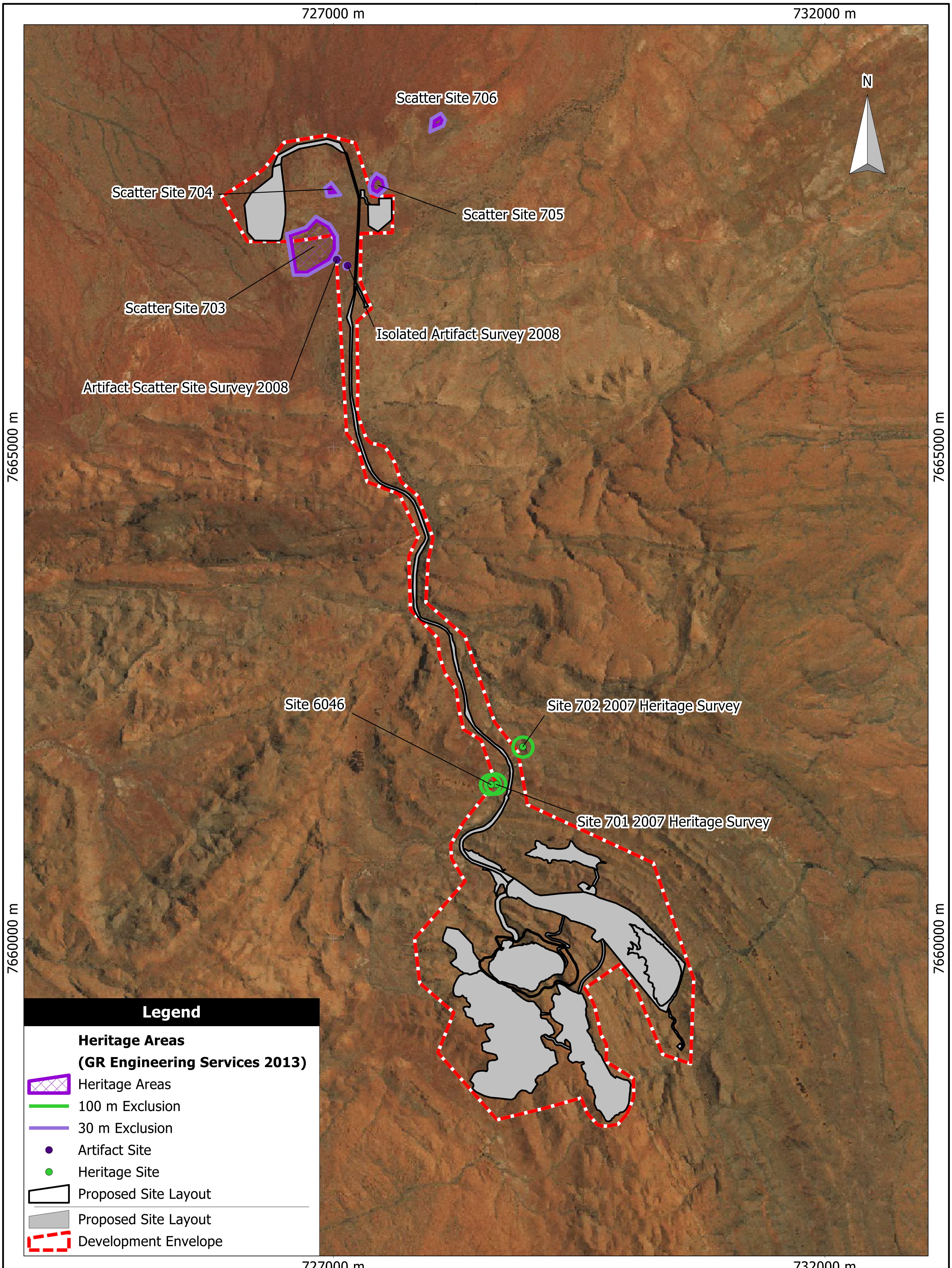


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Image source: Landgate
Air Photo Date: 2012
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**Figure 10**

**Aboriginal Heritage Sites of Significance**

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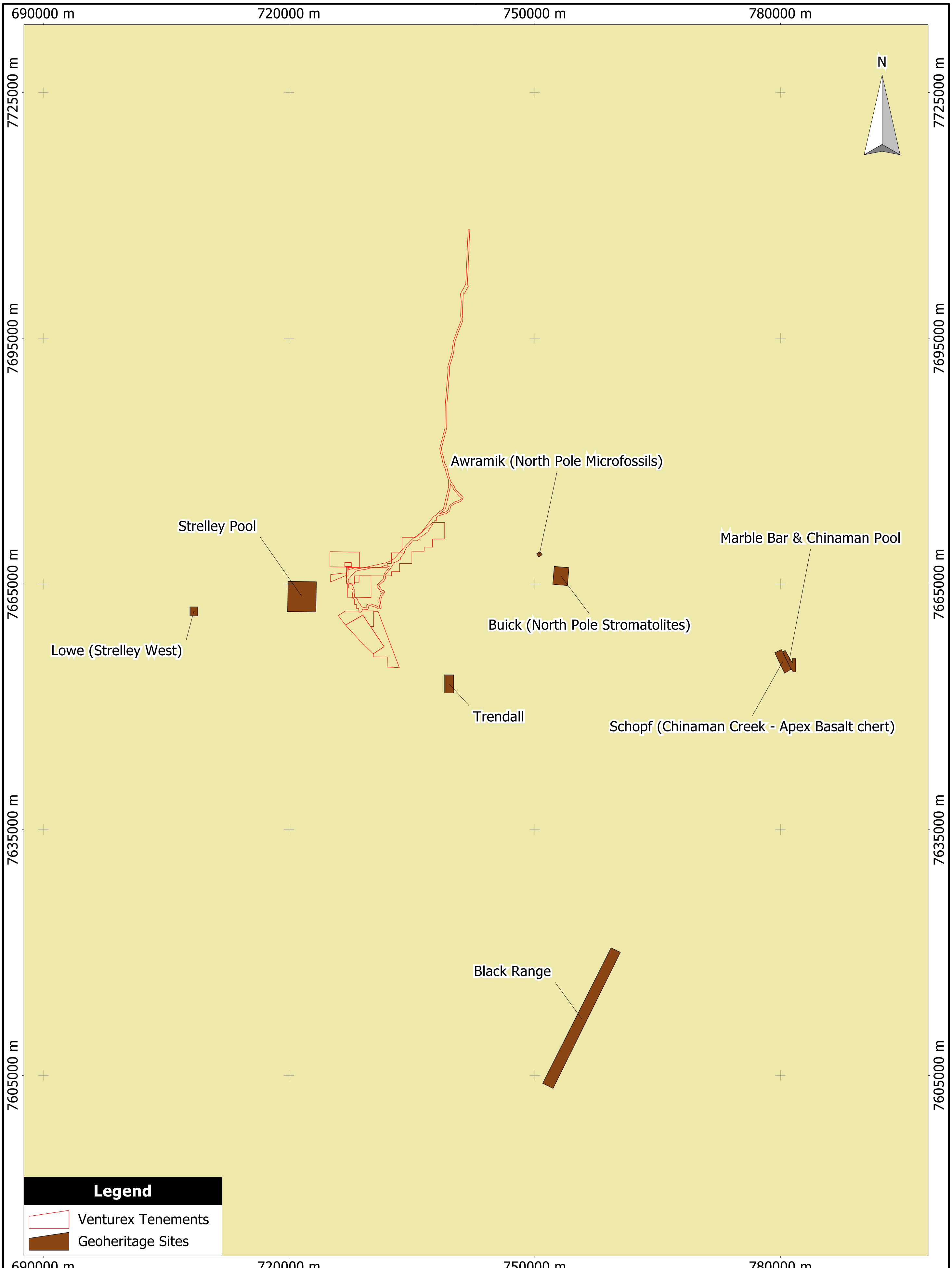


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0 20 km

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**Figure 11**

**Location of Geoheritage Sites**

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# 8. DETAILED PROJECT DESCRIPTION

## 8.1 Project Overview

The conceptual site layout is shown in Figure 3 and further details on each of these elements are provided in the following sections.

## 8.2 Mining

### 8.2.1 Mining Void

The top portion of the Sulphur Springs deposit will be mined via an open pit. The pit will be developed in three stages, with the first stage providing access to ore in the top of the western lode of the deposit and the second and third stages taking the pit to its final limit. (Figure 12).

All material will be mined using conventional drilling and blasting. Weathered material extends to a depth of about 20 m in the area of the mine pit (Entech 2015).

The pit will have a strip ratio of approximately 8.3:1 (including pre strip) resulting in mining approximately 15,800,000 $m^3$ of material. Final pit dimensions will be approximately 450 m wide (north-south), 645 m long (east-west), and 150 m deep. Geotechnical design parameters are summarised in Table 18 (Entech 2015). Final pit floor elevations will be 1,160 mRL and 1,100 mRL in the western and eastern zones respectively.

Surface topography at the orebody is rugged (Plate 4) and the local elevation difference over the 645 m east west extent of the proposed open cut is approximately 100 m. The deposit is centred on Sulphur Springs Creek, with the upper limit of the ore zone at 10 m below the creek level (Entech 2015).

**Table 18: Sulphur Springs Pit Geotechnical Design Parameters (Entech 2015)**

| Pit Wall | From (mRL) | To (mRL) | Batter Angle (degrees) | Batter Height (m) | Degree of Weathering |
|---|---|---|---|---|---|
| North | Surface | 1260 | 56.3 | 20 | Extremely weathered |
| | 1260 | 1240 | 63.5 | 20 | Distinctly weathered |
| | 1240 | Below | 70.0 | 20 | Fresh |
| East | Surface | 1300 | 56.3 | 20 | Extremely weathered |
| | 1300 | 1280 | 63.5 | 20 | Distinctly weathered |
| | 1280 | Below | 70 | 20 | Fresh |
| South | Surface | 1300 | 45.0 | 20 | Extremely weathered |
| | 1300 | 1280 | 55.0 | 20 | Distinctly weathered |
| | 1280 | Below | 55.0 | 20 | Fresh |
| West | Surface | 1300 | 56.3 | 20 | Extremely weathered |
| | 1300 | 1240 | 63.5 | 20 | Distinctly weathered |
| | 1240 | Below | 70.0 | 20 | Fresh |

Initial waste rock produced during pre-stripping to establish the open pit will provide approximately 1.2 Mt of benign material for construction of the processing plant platform, ROM pads, TSF, and access road. Surplus material will be transported to a waste rock dump located to the south (Figure 3). Ore will be hauled to the ROM pad via a haul road across Sulphur Springs Creek (Entech 2015).

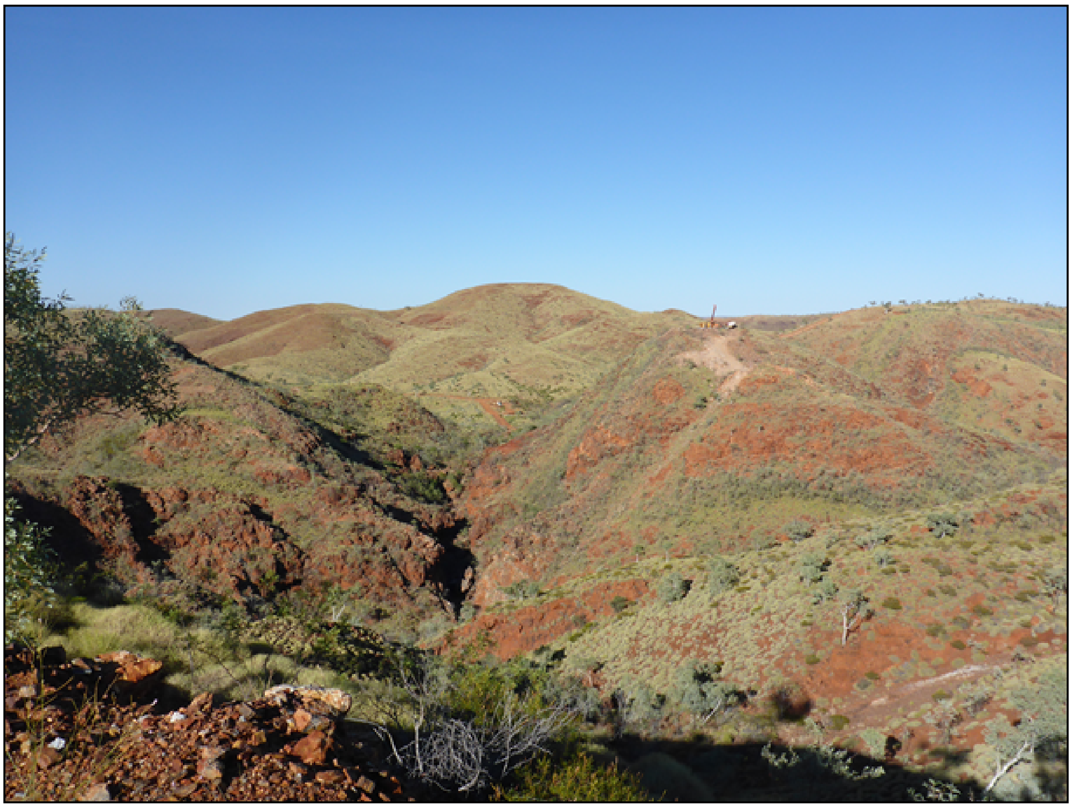


**Plate 4: Site of Proposed Pit Centred on Sulphur Spring Creek**

### 8.2.2 Underground Mine

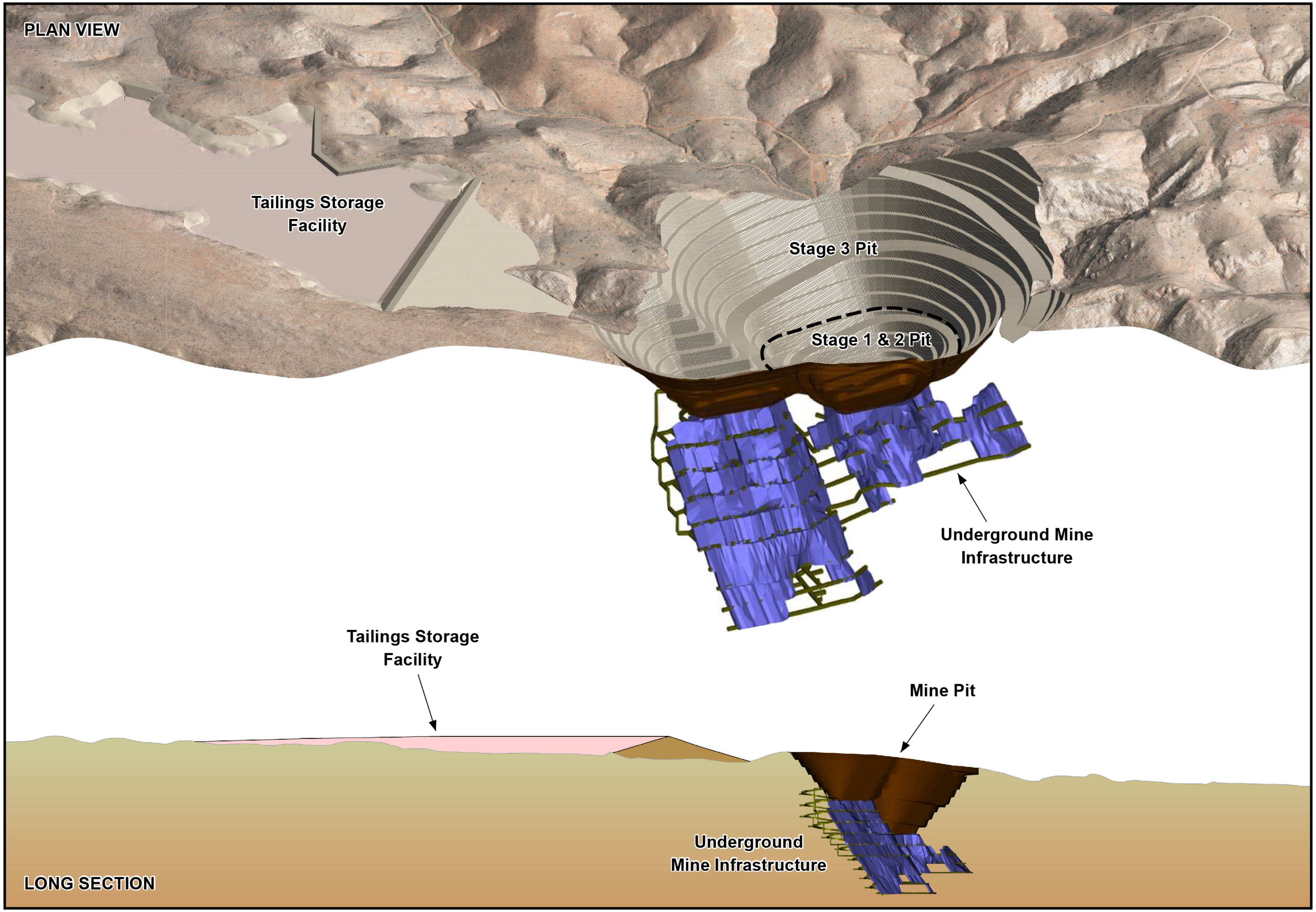
The deeper portion of the deposit will be mined using a primary stoping method referred to as core and shell. This method requires a pattern of generally evenly spaced and sized rib pillars separating the primary (core) stopes, which are connected via an overlying sill pillar. The sill pillar separates the active mining area from the overlying mined out area which contains waste rock fill introduced from a pass breaking through to a designated area in the floor of the pit.

The mine will be developed by a decline system with a mine portal established close to the processing plant.

The underground mine design is shown in Figure 13.

### 8.2.3 Mine Dewatering

A mine dewatering system will be required to allow safe mining during operations. The predicted dewatering volume is approximately 0.64 GL/yr. Dewatering will be effected via a combination of in-pit sumps and groundwater abstraction bores.




Source: Entech 2020

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**Figure 12**

**Open Pit, Underground Mine and Tailings Storage Facility Layout**

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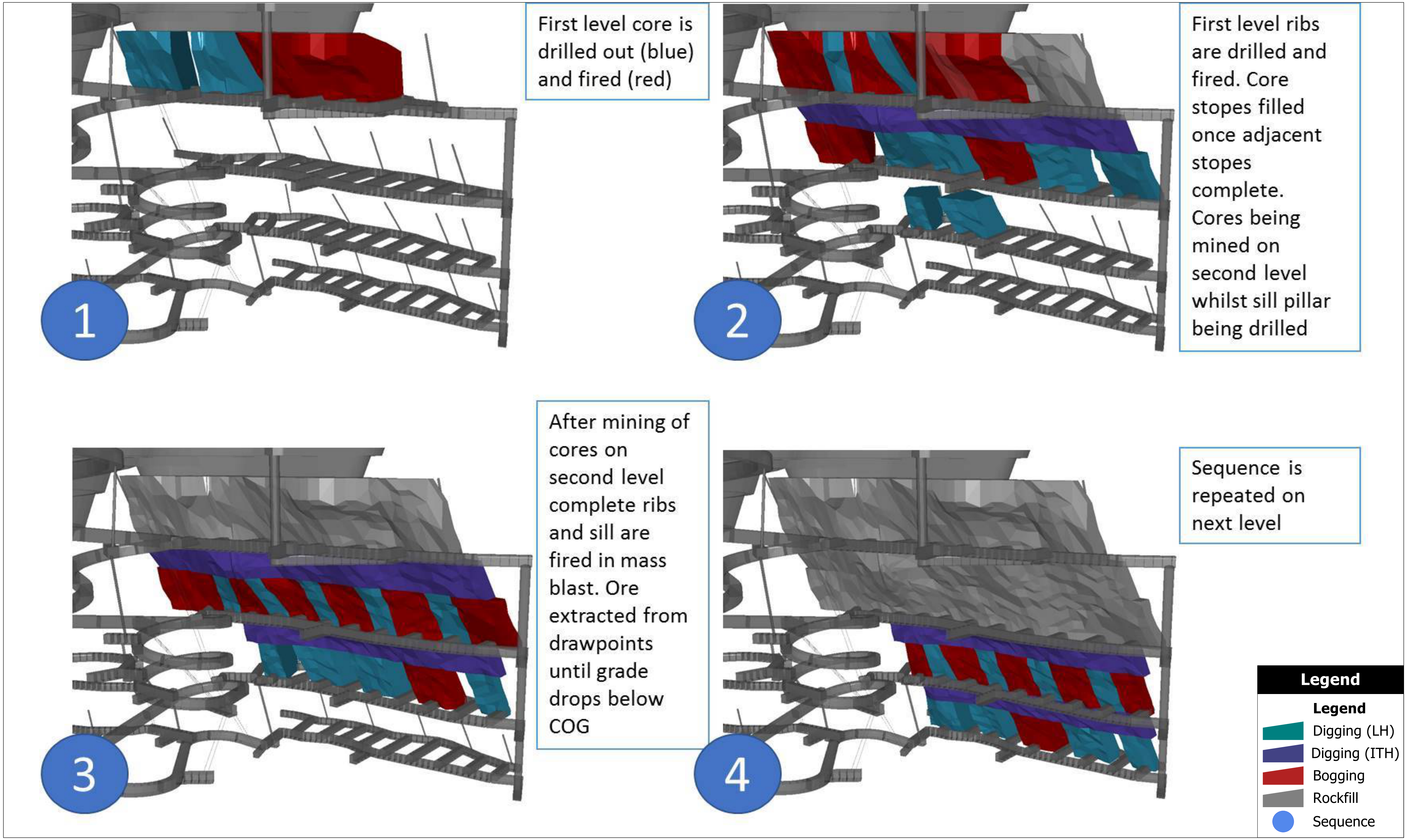


Original Size: A4
Source: Venturex Resources Limited 2018

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**Figure 13**

**Underground Mine Layout**

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### 8.2.4 Pit Lake

The pit will intersect Sulphur Springs Creek near the headwaters of the catchment. Mine pit sub-catchments are shown in Figure 14. During operations, runoff from the sub-catchments upstream of the pit will be intercepted through waste rock and tailings storage landforms. Water from the sub-catchment used for tailings placement will be captured and utilised in processing and intercepted runoff from the WRD catchments will be re-directed to Sulphur Springs Creek downstream of the pit or adjacent Six Mile Creek.

At closure, the mine void will slowly fill with groundwater and rainfall to form a pit lake. The rate of flooding will depend on:

- Storage capacity of the underground mine void.
- Groundwater inflow rates.
- Extent of the immediate pit catchment.
- TSF seepage.
- Direct rainfall.

The volume of surface runoff, governed by the amount of rainfall and extent of the pit catchment, is a dominant influence on the pit water balance and predicted equilibrium water level. Without any diversion of runoff from the pit catchment, the pit lake will slowly fill over 90 – 100 years and is likely to become a groundwater recharge source in the long term (AECOM 2020d). To mitigate this risk, the following sub-catchment modifications are proposed:

- PSC 2 and PSC 3: Final surface of WRD in these sub-catchments shaped to divert a portion of surface runoff into Six Mile Creek.
- PSC 5: Final surface of TSF in sub-catchment shaped to divert approximately 80% of surface runoff into Minnieritchie Creek and/or Six Mile Creek catchments.

Table 19 shows the indicative revised catchment areas following these modifications and Chart 2 shows the predicted pit lake levels over time (assuming annual rainfall of 445 mm (current 30 year average), under different TSF seepage rate scenarios.

**Table 19: Mine Pit Sub-Catchments**

| Sub-Catchment ID | Infrastructure | Pit Sub-Catchment Area (ha) | | Proposed Modifications |
|---|---|---|---|---|
| | | Unmodified | Modified | |
| PSC 1 | Haul road, pit | 29 | 29 | None |
| PSC 2 | Haul road, WRD | 33 | 27.5 | Part of catchments recontoured to drain into Six Mile Creek. |
| PSC 3 | Topsoil stockpile, WRD | 25 | | |
| PSC 4 | Topsoil stockpile | 11 | 11 | None |
| PSC 5 | TSF, service corridors | 55 | 13 | Final TSF surface contoured to drain into Six Mile Creek and Minnieritchie Creek. |
| PSC 6 | Haul road | 3 | 3 | None |
| **TOTAL** | | **156** | **83.5** | |

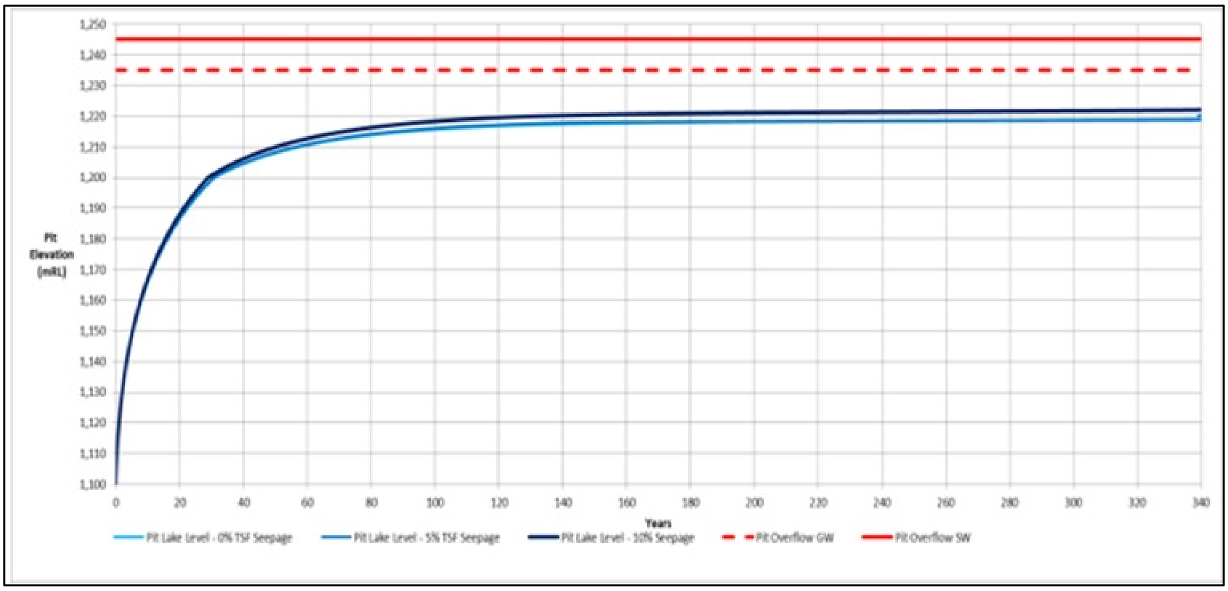



**Chart 2: Predicted Pit Lake Water Levels (Base Case) for a Range of TSF Seepage Rates**

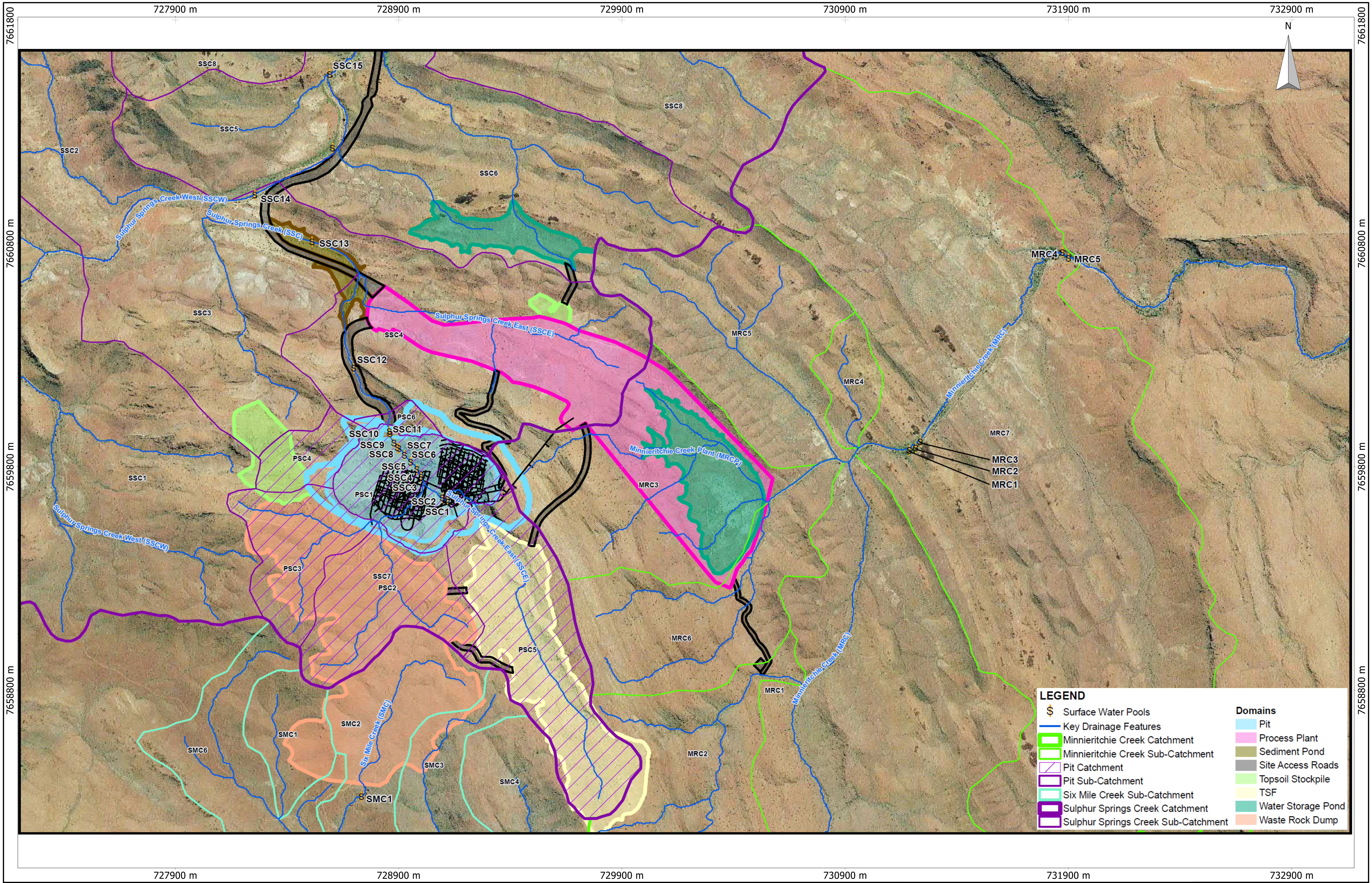
Water in the pit lake is expected to become increasingly saline and contain higher concentrations of most solutes due to evaporation (AECOM 2020d). Modelling indicates pit lake TDS values ranging from 5,259 mg/L (slightly saline) after 100 years to 26,609 mg/L (saline) after 1,000 years. Substantial (>50%) proportions of cadmium, nickel, selenium and zinc inputs are predicted to remain in solution following geochemical equilibration. Concentrations of nickel and selenium may exceed those in existing groundwater within the footprint. All other metal and metalloid concentrations are likely to remain similar to or below those in existing groundwater within the pit footprint (Table 20). Based on predicted TSF seepage quality and alkalinity in the broader aquifer below the mine and TSF area, the pit lake water is expected to be circum neutral.

**Table 20: Predicted Pit Lake Water Quality**

| Parameter | Guideline Value[1] | Existing Groundwater within Pit Footprint | Predicted Pit Lake Water |
|---|---|---|---|
| TDS (mg/L) | 4,000 | 1,010 - 11,600 | 5,259 – 26,609 |
| Cu (mg/L) | 1 | 0.019 - 3.02 | 0.03 |
| Ni (mg/L) | 1 | 0.154 - 0.495 | 0.365 – 1.00 |
| Zn (mg/L) | 20 | 54 - 218 | 14.1 – 33.2 |
| As (mg/L) | 0.5 | 0.4 - 0.52 | 0.0001 |
| Cd (mg/L) | 0.01 | 0.0012 - 0.46 | 0.024 – 0.064 |
| Se (mg/L) | 0.02 | <0.01 - <0.1 | 0.125 – 0.661 |

[1] ANZECC and ARMCANZ (2000): Livestock Drinking Water; NEPC (1999): Investigation levels for livestock; DER (2014): Non-potable groundwater use.

The mine pit lake recovery model and water quality model will be continually refined during the operational phase as more accurate and detailed site data becomes available.




Scale: 1:15000
Original Size: A3
Grid: MGA94(50)

Source: AECOM Sulphur Springs Project Surface Water Assessment 2020

0 1 km

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**Figure 14**

**Pit Area Sub-Catchments**


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W:\Venturex Resources\Sulphur Springs\Projects\2018 ERD\Drawings\Sulphur Springs ERD.map 28/01/2020 MCP F14 Pit Area Sub-Catchments Layout

### 8.2.5 Waste Rock Management

Geochemically benign waste rock from the pit will be used for construction and rehabilitation/closure works where possible and the remainder placed in a single WRD. Geochemically benign material to be used for rehabilitation and closure will be temporarily stored within the footprint of the WRD. PAF waste rock will be preferentially disposed in underground workings where the mine schedule allows. Provision has been made for up to 8.1 Mt of this material to be encapsulated within the WRD.

The WRD will be constructed within the valley to the southwest of the pit for disposal of up to 41 Mt of waste rock from the pit (Figure 3). The waste rock placement strategy will approach that of a valley fill with the northern and southern outer walls of the WRD constrained by the valley ridgelines. Plate 5 shows the northern ridgeline for the WRD site. Design features for the WRD are summarised in Table 21.

**Table 21: Waste Rock Dump Design Details**

| Dimension | WRD |
|---|---|
| Height | No higher than surrounding topography (up to 1,370 mRL) |
| Length | Approximately 1,400 m |
| Width | Approximately 1,000 m |
| Waste Rock Storage | Approximately 40 Mt (including up to 8.1 Mt PAF) |
| Final Footprint | 79.6 ha |
| Final Slope Angles | 16 to 20º |
| Waste Type | PAF encapsulated in engineered cells within NAF material. |

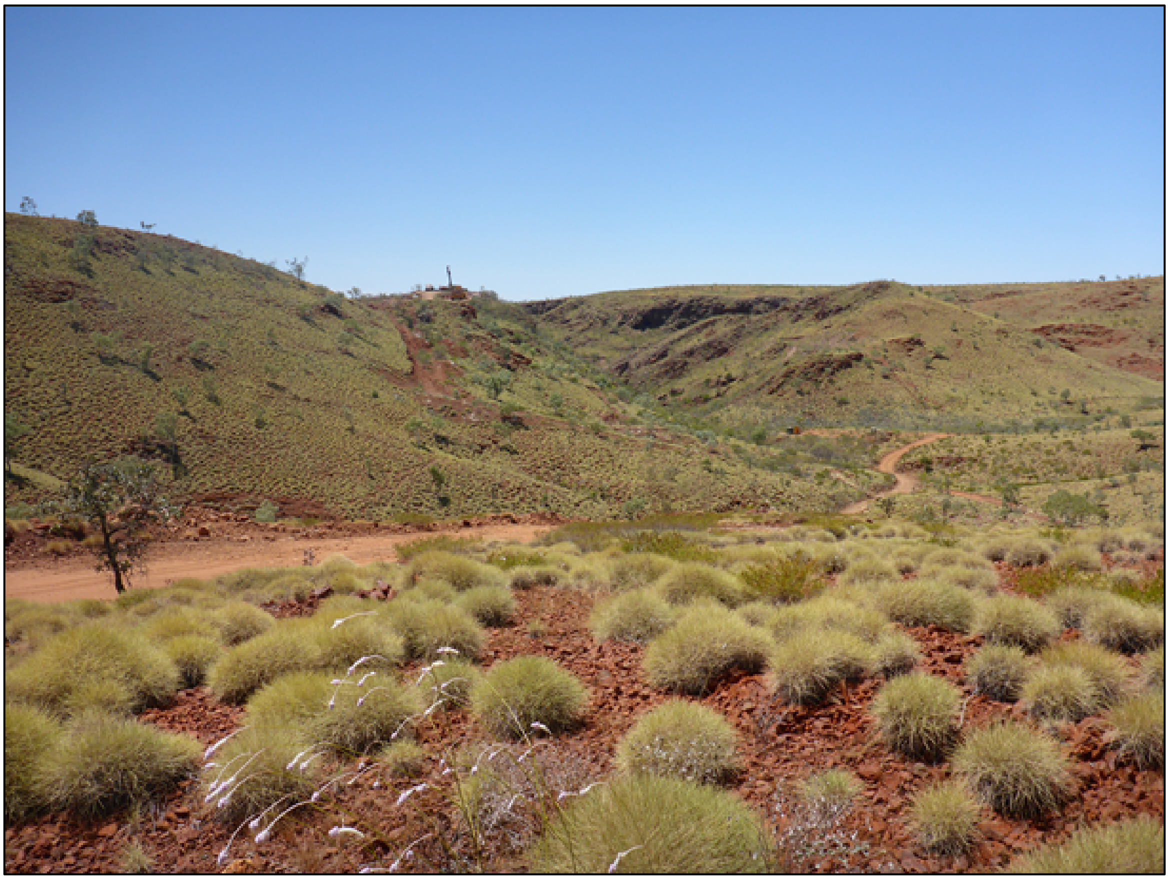

**Plate 5: Valley Fill Site for WRD (Looking North)**

PAF waste to be stored in the WRD (about 20% of its total volume) will be encapsulated in cells to limit the potential for oxidation. All encapsulation cells will be located in the northwest corner of the WRD (Figure 15), within the catchment of the pit, so that any seepage will be captured within the mine dewatering system during operations and migrate to the pit lake post closure.

Conceptually, PAF cells will have a minimum 5 m thick base, a minimum 10 m wide selvage on the outer edges and a minimum cover of 5 m. The base, selvage and cover will be constructed of NAF material placed in layers less than 3 m thick and compacted by heavy vehicle traffic. A typical cross section of a PAF encapsulation cell within the WRD is shown in Figure 16.

After each cell is filled with PAF material, the stockpile will be compacted to achieve uniform consolidation, maximise evaporation of any rainwater and minimise preferred pathway infiltration. Once a PAF encapsulation area reaches capacity, a NAF layer will be placed over the waste. In accordance with the progressive rehabilitation schedule the entire area will be covered with NAF waste and shaped in accordance with final mine closure design requirements as part of the larger WRD. The WRD reaches its maximum size by the end of Year 4 as the mining operations transition from open pit to underground. All underground waste will either be stockpiled in the base of the pit or used to backfill underground workings.

The PAF encapsulation cells will be designed to capture incidental rainfall only during operations (Years 1-4). Drainage designs will be engineered to prevent surrounding runoff from entering the area. External drains will divert rain from other areas of the WRD away from the depositional areas. Surface water runoff from outside the WRD will be diverted by permanent stormwater structures designed and operated to convey and withstand a 1 in 100-year storm event.

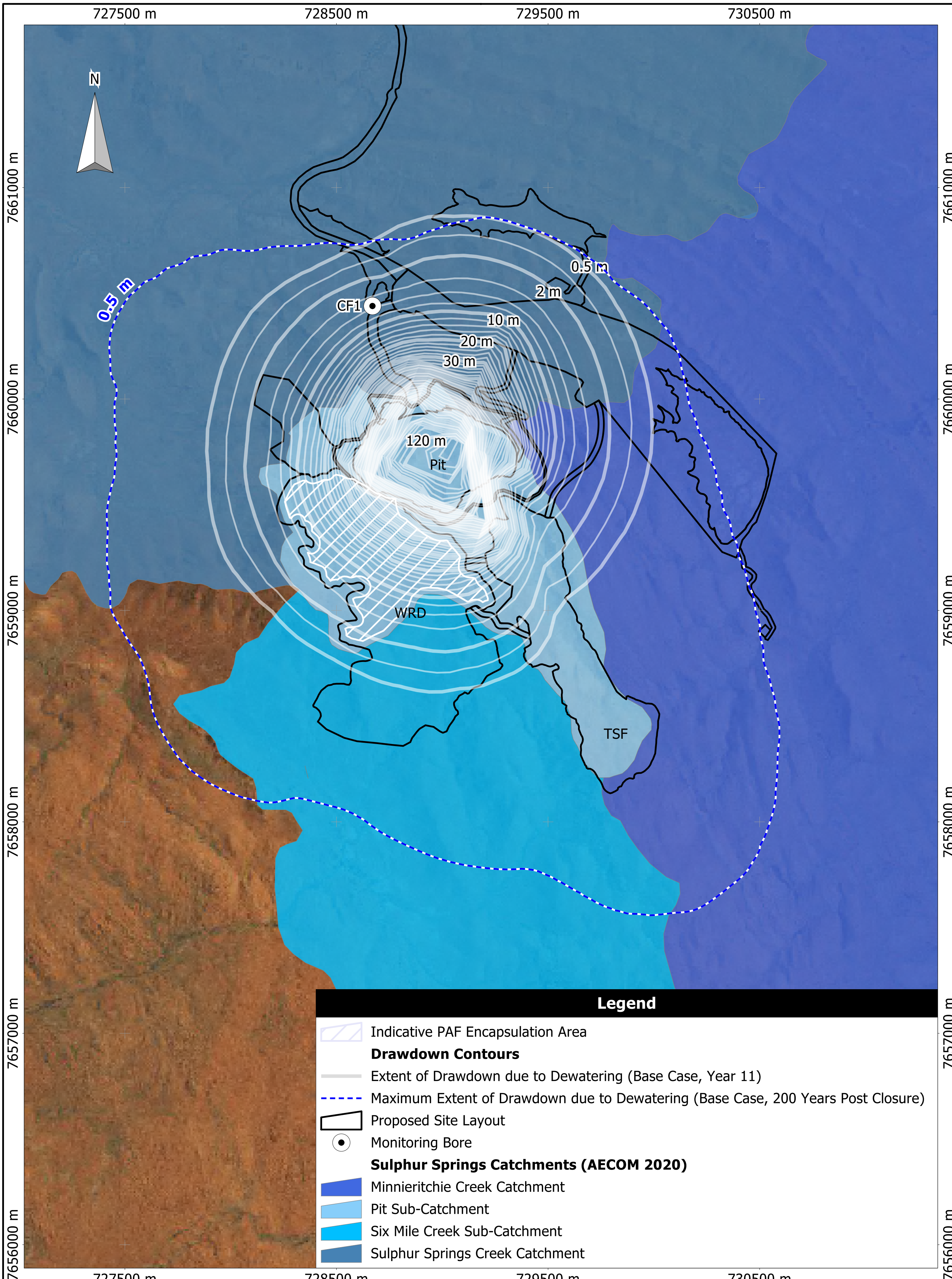


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**Figure 15**

**PAF Encapsulation Area Within Groundwater Drawdown Area**


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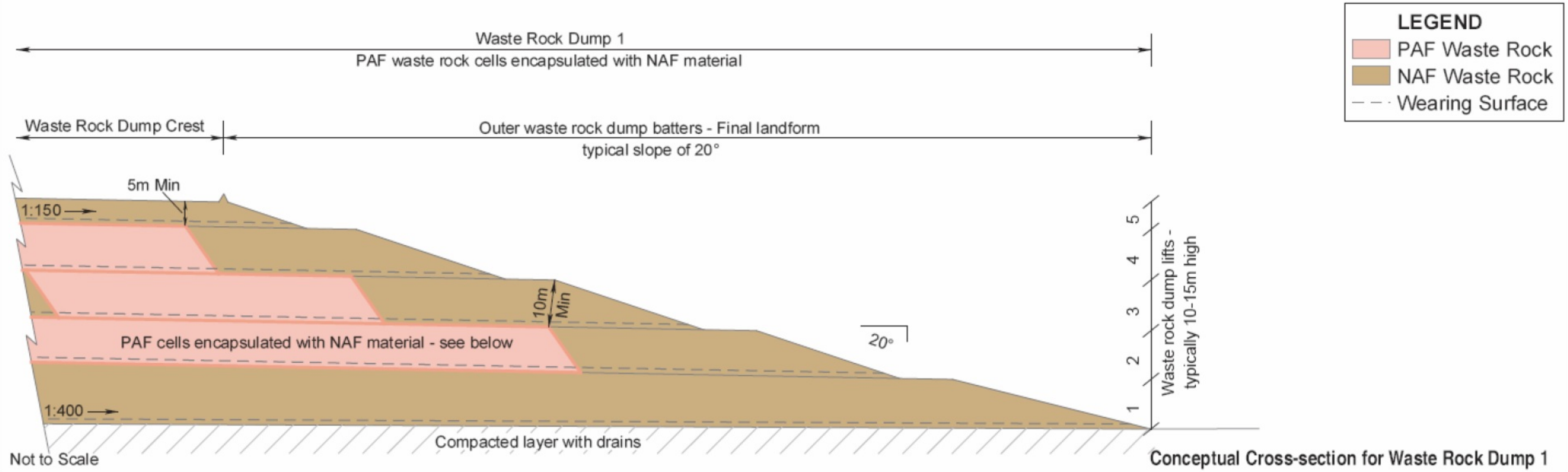
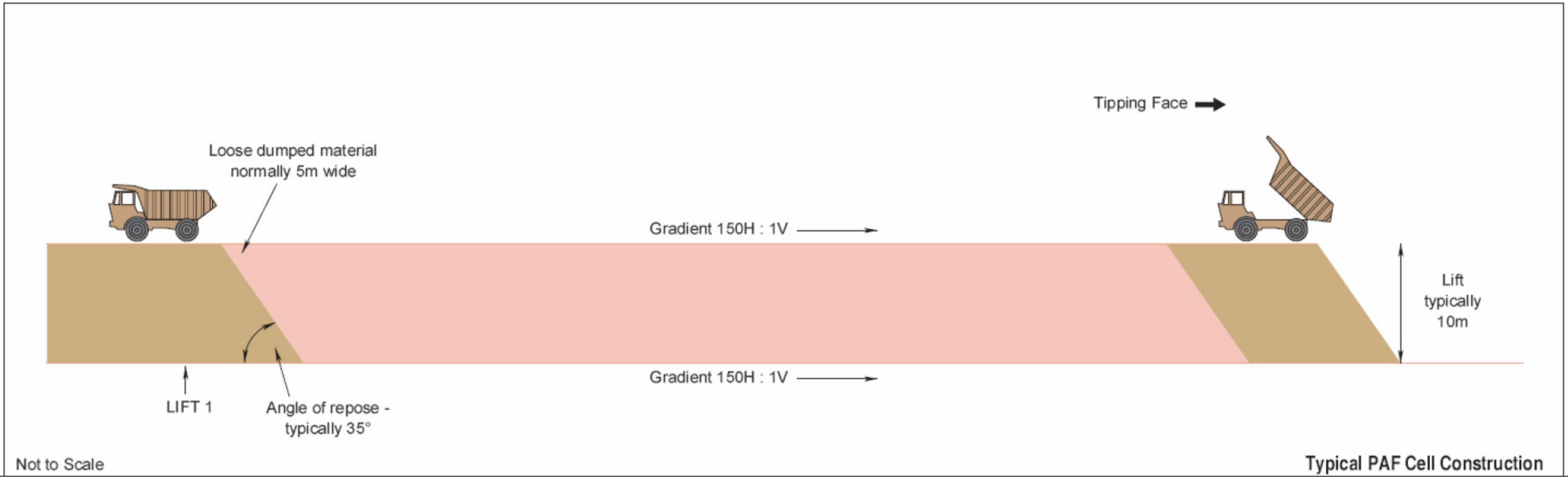



Conceptual Cross-section for Waste Rock Dump 1




Typical PAF Cell Construction

Not to Scale
Original Size: A4
Source: URS 2007

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**Figure 16**

**PAF Encapsulation Cell Schematic**

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## 8.3 Processing Plant

### 8.3.1 Location

The 1.5 Mtpa processing plant will take Run of Mine (ROM) ore and concentrate the copper and zinc bearing minerals to produce separate copper and zinc concentrates and a barren tailings stream. The plant will be sited in the valley to the north of the pit where the terrain is relatively flat (Figure 3, Plate 6 and Plate 7).

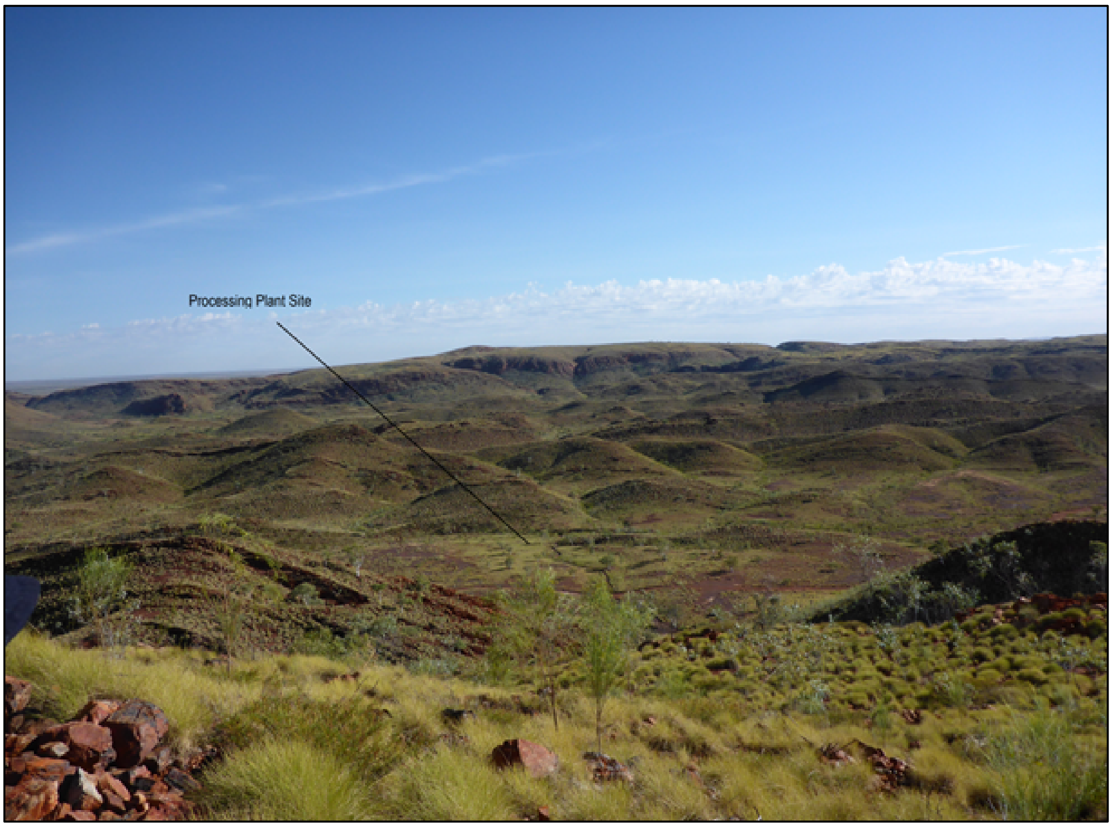


**Plate 6: Processing Plant Valley Site (Looking North)**

**Plate 7: Processing Plant Site**

### 8.3.2 Processing Plant Design

Ore will be reclaimed from the ROM and directly fed into the primary crusher with final crushed ore being discharged to a surge bin. Primary crushed ore from the surge bin will be conveyed to a Semi-Autogenous Grinding (SAG) mill. The ground ore which passes through the SAG mill trommel screen will report to a dedicated SAG mill discharge hopper from which it will be pumped to a cluster of classification hydrocyclones. The coarse underflow will gravitate back to the SAG mill. The finer overflow will gravitate to the ball mill discharge hopper.

Slurry from the ball mill discharge hopper will be pumped to a second cluster of classification hydrocyclones and the coarse underflow will gravitate to a ball mill. The discharge from the ball mill will gravitate into the ball mill discharge hopper. Overflow from the second cluster of hydrocyclones, at 35% solids and an 80% passing size ($P_{80}$) of 63 µm, will gravitate to the copper flotation circuit an agitated copper conditioning tank where reagents (including sodium metabisulphite, collector (A3894) and lime) are added to the slurry. Slurry is then directed to the head of the copper flotation circuit where methyl isobutyl carbinol (MIBC) is added to act as a froth stabilising agent. The copper flotation circuit consists of six copper rougher/scavenging cells and two stages of four cleaner cells.

Concentrate from the copper rougher/scavenger cells will gravitate to a cleaner flotation circuit, where the concentrate is further upgraded. Concentrate from the second cleaner stage forms the final copper concentrate and will be pumped to the copper concentrate thickener. Tailings from the copper rougher/scavenger flotation cells will be directed to the zinc conditioning tank where reagents (including potassium amyl xanthate (PAX), copper sulphate and lime) are added to the slurry.

The zinc flotation circuit is similar to the copper circuit. Its configuration includes six rougher/scavenging cells and two stages of four cleaner cells which produce a zinc-rich product and a barren tailing. Tailings from the zinc cleaner circuit are returned to the zinc rougher/scavenger cells and final concentrate recovered from the second cleaner stage reports to the zinc concentrate thickener. Tailings from the zinc rougher/scavenger circuit will be pumped to the tailings thickener.

Process reagents will include lime, sodium metabisulphite, A3894 copper collector, methyl is butyl carbine (MIBC), potassium amyl xanthate (PAX) zinc collector, copper sulphate activator, and flocculant. All chemical reagents will be stored within tanks in appropriately bunded facilities whereby 110% of the largest vessel is contained and 25% of the total volume is contained according to *Australian Standards AS1940* and *AS1692*. Stocks of reagents will be stored in a designated Reagents Shed, appropriately designed to comply with all relevant legislation.

## 8.4 Tailings Storage Facility

A valley-fill TSF will be constructed in the valley to the southeast of the pit (Figure 3). The overriding rationale for selection of this site is that it lies within the long term hydraulic capture zone of the mine pit. Seepage from the TSF at closure will report to the pit, which will remain a perpetual groundwater sink with implementation of catchment modifications shown in Table 19.

The conceptual TSF design comprises a cross-valley storage and has been assessed as a 'High B' consequence category using the Australian National Committee on Large Dams (ANCOLD) *Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure – Revision 1* (ANCOLD 2019, KPC 2020). As the final embankment height will exceed 15 metres, the TSF is classified 'Category 1' in accord with the Code of Practice *Tailings storage facilities in Western Australia* (DMP 2013a) and the detailed design will comply with the *Guide to Departmental Requirements for the Management and Closure of Tailings Storage Facilities* (DMP 2015). The TSF design comprises:

- An element over overdesign to be satisfied that the facility/valley can retain the proposed volume of tailings (8.8Mt), maintain adequate freeboard for high rainfall and can accommodate a potential mid-valley embankment to establish 2 cells within the facility (refer to Section 2.2.6.5 below).
- A Main and South Saddle Embankment, constructed in a downstream configuration in stages to suit the valley profile and rate of tailings generation. The embankments will be constructed as multi-zoned earth and rockfill and include a low permeability zone won from local borrow or benign mine waste, conditioned and compacted. The downstream structural zone will be constructed of selected weathered mine waste from the open pit placed, moisture conditioned and compacted by heavy vehicle traffic (Figure 12).
- Three secondary saddle dams, potentially required along the western perimeter late in the project life (years 7 - northern-most dam; year 9 - central and southern dams). Construction of the northern-most saddle dam will be undertaken in Year 7 of the LOM in the event projections of the tailings surface at the time indicate the dam is warranted to ensure protection of three *Pityrodia sp*. Marble Bar individuals on the western flank of the TSF (Figure 12). The timing and location are adjusted slightly from the conceptual design proposed by Knight Piésold (Appendix 4).
- A partial basin underdrainage system comprising main collector drains along part of the basin spine designed to drain by gravity to a collection sump located at the toe of the main embankment.
- Deposition of tailings from both the Main and South Saddle Embankment. Deposition modelling undertaken using the RIFT TD tailings modelling package indicates the supernatant pond will form towards the centre of the facility. Decants will be used to return supernatant to the water treatment plant prior to reuse in the processing plant.
- Cycling of tailings deposition to ensure exposed beaches are re-wet at least every two weeks to assist in maintaining high tailings saturation levels.
- Monitoring bores installed to monitor the phreatic surface within the embankments and groundwater levels/quality downgradient of the embankments. Select bores will be sized such that they can be converted into recovery bores to abstract water if required.
- Covering the final tailings surface with a 'store and release cover' incorporating a low permeability capping that minimises infiltration to the tailings surface and a NAF waste rock layer placed to ensure contours shed surface runoff to the south into the adjacent Six Mile Creek and Minnieritchie Creek catchments.

The conceptual layout of the TSF is shown in Figure 17. The TSF design and tailings deposition model will be finalised after the completion of further site specific studies to be completed in the first half of 2020. The Mining Proposal and MCP to be submitted to DMIRS for assessment will incorporate the finalised design.

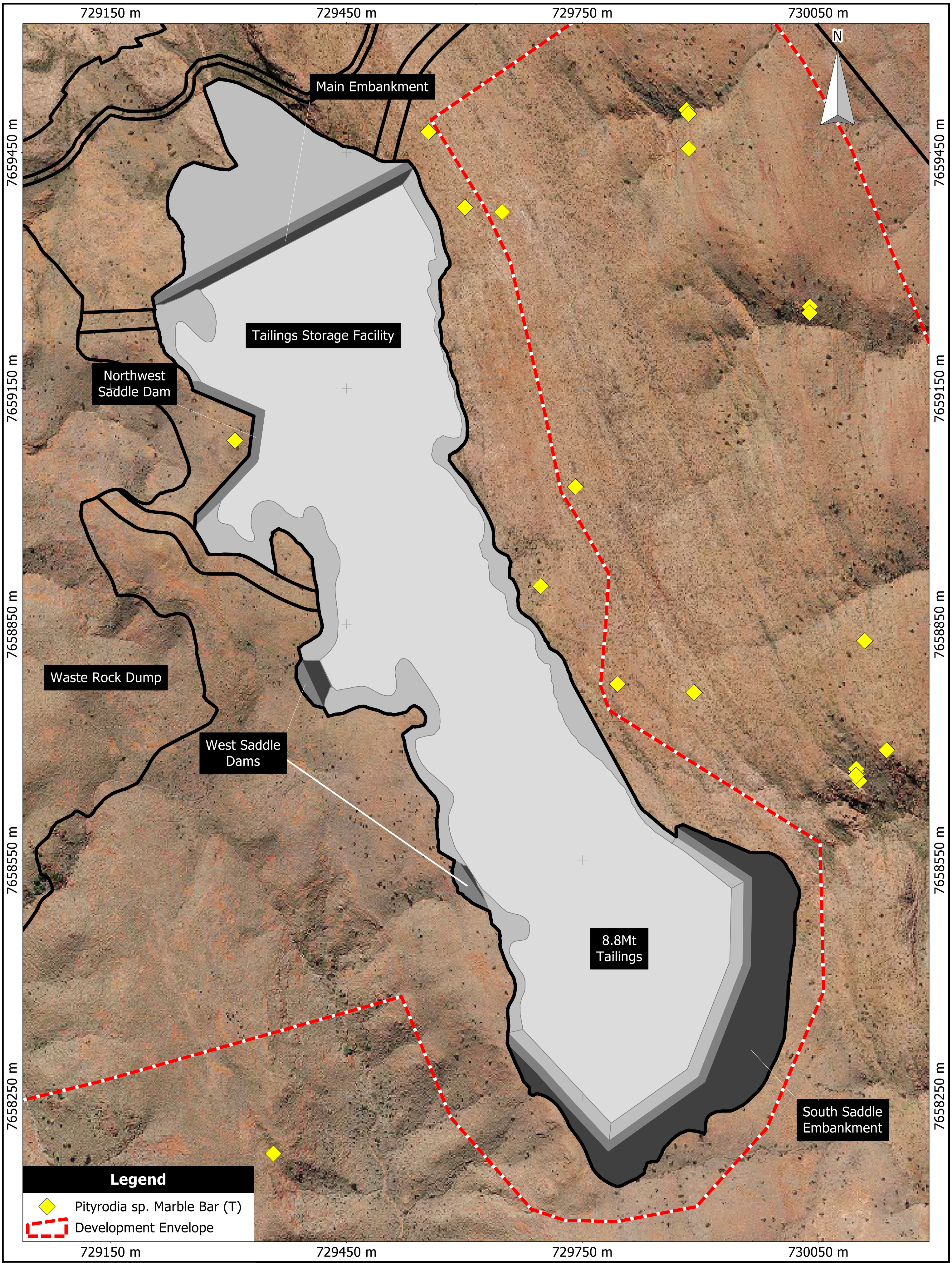


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**Figure 17**

**TSF Conceptual Design**


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## 8.5 Water Storage

Surplus mine dewater will be directed to one of two HDPE lined evaporation ponds (North Pond and South Pond) for subsequent use in ore processing (minus water lost to evaporation). TSF decant water will also be stored in these structures when not immediately recycled through the water treatment plant to the processing circuit. North Pond will be located in the Sulphur Springs Creek catchment, downstream of the pit and South Pond will be located in the Minnieritchie Creek catchment, adjacent and to the east of the processing plant (Figure 3). The ponds, 27.7 ha in total, will be constructed and managed during the operations phase to industry standards that will include measures for seepage detection and, if necessary, recovery.

## 8.6 Surface Water Management

During mining operations potential impacts will be managed by:

- Surface water diversion, settling basins and site water ponds that will minimise risks to downstream environments from areas with the potential to generate low quality runoff.
- Early rehabilitation of disturbed ground, such as WRD outer slopes and borrow areas.
- Treating water to enabling recycling through the processing circuit so as to minimise the storage of poor quality water and the risk of surface discharge.
- Abstracting groundwater for make-up supplies (when required) in a way that minimises drawdown impacts on riverine environments.

During and following closure, potential impacts will be managed by:

- Appropriate landform design, construction and rehabilitation of the WRD and TSF to minimise erosion risk. Remediation of erosion damage during the early establishment of vegetative cover.
- Removal of any residual PAF material and other potentially contaminated materials which can be placed underground or at the base of the mine pit.
- Reinstatement of pre-mining surface flow patterns to the greatest extent possible such as at the plant area and water storage ponds.
- Appropriate drainage channel design, armouring and revegetation where permanent surface water diversion structures are required (e.g. re-contoured sub-catchments around the mine pit).

Preparatory measures for closure, the outcomes of which will be reflected in revisions of the MCP will include:

- Refinement of the pit hydrology and model based on data gained during operations (e.g. aquifer yields and transmissivity).
- Refine pit catchment modification designs to further reduce risk of the mine pit overtopping post closure. This includes examination of, opportunities to divert a greater proportion of the pit catchment away from the pit lake.
- Review monitoring data during the operational phase including groundwater levels and quality downstream of the main and southern TSF embankments to determine the risk of seepage and implement recovery measures if warranted.
- Regular re-evaluation of the ecological risk assessment within both the Sulphur Springs and Minnieritchie creek catchments to inform final post closure drainage design engineering options.

## 8.7 Project Water Requirements

Water will be required for construction and operation of the Project. Key water uses include potable water at site offices and the accommodation village, process water for the plant, underground development, maintenance of infrastructure such as access roads, and dust suppression.

A summary of Project water requirements is provided in Table 22.

Mine dewatering will provide the majority of water required for the Project. Initial dewatering will be achieved with bores equipped with electric submersible pumps. As mining progresses, sub-horizontal drain holes will be drilled in the pit wall to complement the dewatering bores. Nominal bore locations are shown in Figure 18.

**Table 22: Project Water Requirements (AECOM 2020c)**

| Water Use | Water Volume Required (kL/day) | Source/s |
|---|---|---|
| **Construction Phase** | | |
| Site Office | 50 | Bore SSWB06 |
| Construction and Dust Suppression | 800 | Bores SSTP01, SSTP03, SSWB12 and SSWB20 |
| **Total** | **850** | |
| **Operations** | | |
| Processing | 1,600 | Mine Dewatering |
| Underground Mine Development | 400 | Mine Dewatering |
| Accommodation Camp | 50 | Potable Bore |
| Access Road Maintenance | 1,000 | SSWB36, SSWB38, SSWB40 and PAN60 |
| Site Dust Suppression | 600 | Bores SSTP01, SSTP03, SSWB12 and SSWB20 |
| **Total** | **3,650** | |

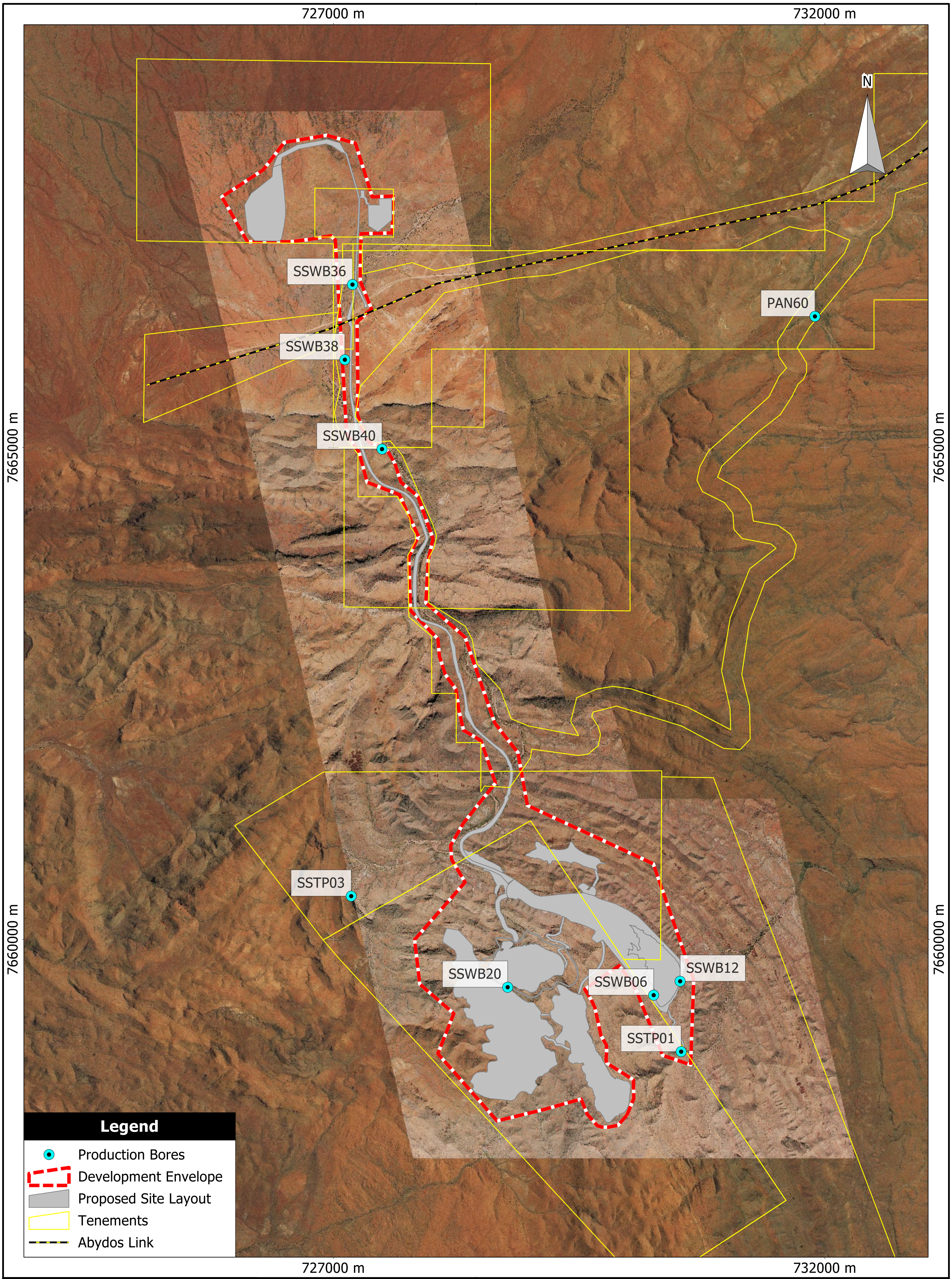


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**Figure 18**

**Groundwater Abstraction Bores**

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## 8.8 Access Roads

An 8.2 km access road (referred to as the site access road) connecting the mine site to the Abydos link will be constructed along the route shown in Figure 3. The northern portion of this route traverses open plains and gentle slopes and the southern section a series of steeper gorges and valleys.

Two creek crossings are required along this route where cross-cutting valleys direct water into Sulphur Springs Creek. The crossings have been designed to handle predicted creek flows resulting from a 72 hour 1 in 100 year event, without overtopping. In the event of shorter, higher intensity storms the road may overtop for short periods.

The road will be designed to accommodate heavy vehicles and two way traffic. It will be a nominal width of 12m and constructed with drains on both sides.

## 8.9 Other Ancillary Infrastructure and Services

Other ancillary infrastructure and services for the Project will include:

- **Power Station**: Power will be supplied from a diesel and/or liquified natural gas (LNG) fired power station. The facility will consist of 5 x 2 MW gensets. Power will be generated at 11 kV and reticulated to two substations; one at the primary crushing area and one next to the grinding mills. Power will be stepped down to 415 V for reticulation to the remainder of the process plant.
- **Accommodation Village:** A 200 room permanent village will be established on site and an additional, temporary camp will be installed for construction. The nearby Abydos accommodation village will also be utilised, if required, for any additional accommodation required during construction. The village will be powered by a standalone generator.
- **Laydown Areas:** Two laydown areas (plant and core yard) will be established for the Project.
- **Fuel Storage:** Diesel will be stored in 110 kL self-bunded tanks. Natural gas, delivered to site via road tankers, will be stored in vacuum insulated vessels in proximity to the power station. Fuel storage facilities will include a fuel unloading system, access, lighting and all necessary safety systems. A single (110 kL) self-bunded diesel tank will be installed at the accommodation village to supply the standalone generator.
- **Other Buildings and Services**: A number of support buildings including a laboratory, administration office, first aid centre, crib room, mine office, plant office, workshop/warehouse, WWTP’s, control room, and ablutions will be constructed for the Project.

## 8.10 Disturbance and Landforms at Completion

The mining landforms expected to remain at the completion of operations are summarised in Table 23, and shown on Figure 13.

**Table 23: Mining Landforms**

| Landform | Footprint (ha) | Height/Depth (m) | MRF Category | MRF Class |
|---|---|---|---|---|
| Open pit | 28.9 | 150 | Mining void >5m deep, below water table | B |
| WRD | 79.6 | 60 - 80 | Waste rock dump class 1 | A |
| TSF | 42 | 55 | Tailings storage facility class 1 | A |

The finalised disturbance footprint will be detailed in the Mining Proposal to be submitted with an up-dated MCP to DMIRS for assessment.

# 9. IDENTIFICATION AND MANAGEMENT OF CLOSURE ISSUES

## 9.1 Principles

A risk assessment for the Sulphur Springs Project has been developed and included in the ERD. A preliminary assessment of the principal closure risks identified for the Sulphur Springs Project, and mitigations or management measures in place or proposed for each risk, is provided in Appendix 3. The risk assessment is based on principles set out in AS/NZS ISO 31000:2009 *Risk Management - Principles and Guidelines* and adopts definitions of likelihood and consequence that have been used to evaluate each risk as it stands (inherent risk), and determine whether it is tolerable (requiring no further management), or requires further management.

The risk assessment considers how, and to what extent, aspects discussed in Section 7 threaten the objectives and post-mining land uses (Section 5) and fulfilment of obligations (Section 3). The assessment also considers what controls or mitigations will be present. The risk of each hazard is determined by identifying the worst realistic consequence (for health, safety, environment, cost, or reputation) and the likelihood of that consequence. The risk is then classified according to a risk classification matrix (Appendix 3) .

Where a risk is not considered tolerable, additional controls are proposed, and the residual risk after these additional controls is evaluated and classified according to the same method. These controls are integrated into implementation, monitoring and maintenance plans (Sections 10 and 11) and accounted for in financial provisioning (Section 12). Where a significant risk is characterised by material uncertainty or lack of information, the knowledge gap is identified and targeted for further study (Section 7.22). Risk provisions (Section 12) will be made to allow for residual risks or uncertainty after the application of controls.

As the Project is at a planning stage and the organisational structure not finalised, responsibilities for closure risk management measures have not been assigned to particular positions, and broad timeframes described. More specific allocation of responsibilities and timeframes will be set out in subsequent revisions of this MCP.

## 9.2 Principal Risks

The most significant risks identified for closure of the Sulphur Springs Project at this stage of the Project are:

- Landform instability resulting in loss of containment from the TSF and to a lesser extent the WRD.
- Ineffective drainage control (TSF seepage and surface runoff) resulting in the discharge of contaminated water.
- Ineffective pit sub-catchment modifications resulting in pit lake discharge (via overtopping or seepage).
- Premature closure of the mine, potentially leading to a shortfall of NAF oxide mine waste material for covering the waste rock dump PAF cells and tailings, and potential exposure of PAF material in partially developed mine pit.
- Ineffectual mine closure planning resulting in underestimation of possible closure costs and an inappropriate Closure Provision.
- Ineffective safety measures both during closure operations and post closure resulting in injury or death to workers or the general public.

These closure risks are discussed in greater detail in Section 9.3 and influence the closure strategies detailed in Section 10.

## 9.3 Risk Management

Fit for purpose mitigation and management measures developed address the above risks are outlined in the sections below.

### 9.3.1 Landform Instability

Landform instability relates to possible uncontrolled geotechnical instability of both the mine waste landforms and the mining area (open pit and underground workings). Severe slumping or collapse could pose a serious safety or environmental risk. Operational stability modelling is generally focused on short to medium timeframes whereas closure planning has to consider timeframes that extend over 100's of years. Detailed closure design work will take place once the construction designs have been finalised and LOM design drawings are available.

Mine waste landform closure designs will be focused on achieving long term geotechnical stability of outer batters as well as on internal terraced (flats) areas. Closure strategies will be based on engineering and scientific proven designs and specifications based on longer time frames than those used for operational purposes. When embankments designed to retain mine waste materials and/or water exceed threshold heights, the structures are required to meet nationally regulated engineering standards and specifications. In the case of WRD embankments working faces will be maintained at appropriate safety angles for the relevant machinery. All batter outer surfaces will have adequate mine waste rock covers to control excessive gully erosion that might if left unchecked lead to geotechnical instability and possible exposure of dispersive or PAF material.

The long-term geotechnical stability of all mine workings, both open cut and underground, will be assessed by suitably qualified professional staff in the period leading to closure to ensure that any potential zones of instability are identified and precautionary action can be taken. This could entail buttressing, backfilling, slope re-profiling or isolation by means of bunding and appropriate signage.

Geotechnical stability monitoring will be established during operations and will continue throughout the post closure monitoring phase.

### 9.3.2 Ineffective Drainage Control Leading to Contamination of the Wider Environment

Drainage control relates both to the volumetric discharges and water quality impacts within the three major Project catchments. Ineffective drainage control post closure can reduce surface and ground water quality due to discharge of contaminants and increased turbidity and sedimentation. The critical mine waste landforms/structures that remain post closure are the WRD, TSF and mine pit. This section addresses impacts relating to closure of the WRD and TSF. The pit lake is discussed in Section 9.3.3.

The quality of surface water runoff from the rehabilitated WRD and TSF landforms is expected to improve relatively soon after closure. Initially, surface water discharges from these newly created surfaces may contain raised levels of sediment and turbidity which is expected to decrease as the freshly rehabilitated surfaces stabilise. Any early vegetation growth on the WRD will help reduce raindrop erosion on sloping surfaces. Sediment traps installed during the operational phase are likely to be retained in the early period of closure, depending on the rehabilitation timing within the relevant catchment. These will require maintenance (removing accumulated sediment) until the landform stabilises, which is expected to be similar to a normal post closure monitoring period in the order of 10 years.

A proportion of the WRD is located within Sulphur Springs Creek catchment and runoff from the northern batters will report to the mine pit. Runoff from the majority of the WRD will be directed to the neighbouring Six Mile Creek catchment. Seepage through the WRD will be captured within the mine pit drawdown cone. Contaminant loads in seepage are expected to be insignificant as the majority of the material will be NAF, generally unreactive, and net seepage rates (amount passing through the cover) are expected to be small. The PAF cells will be placed upgradient and in the natural catchment of the mine pit and any seepage will also report to the mine pit.

The portion of the WRD located within the Six Mile Creek catchment is not expected to result in material changes to the local groundwater recharge rate and possible water table rises are considered unlikely to result in any significant change to flow/discharge rates downstream in this catchment (AECOM 2020a).

Additional mitigation and management measures that will be implemented to minimise environmental impacts from drainage will include:

- Potential sources of sedimentation and contamination will be removed and remediated as required. The most likely source of sedimentation during operations will be a large stockpile of growth medium, which will be reused on site as part of closure activities.
- Prior to closure, Venturex will:
  - Review the need to retain contaminants and sediments from WRD seepage and runoff.
  - Refine the pit lake model as part of closure planning. This model will inform surface water design and management measures required to ensure the pit lake maintains a hydraulic sink within the local water table.
  - Ensure that closure of the WRD incorporates an engineered cover, designed to minimise ingress of air (oxygen) and water to the encapsulated PAF areas, therefore reducing the potential to generate AMD.

### 9.3.3 Ineffective Pit Sub-Catchment Modifications Resulting in Pit Lake Discharge

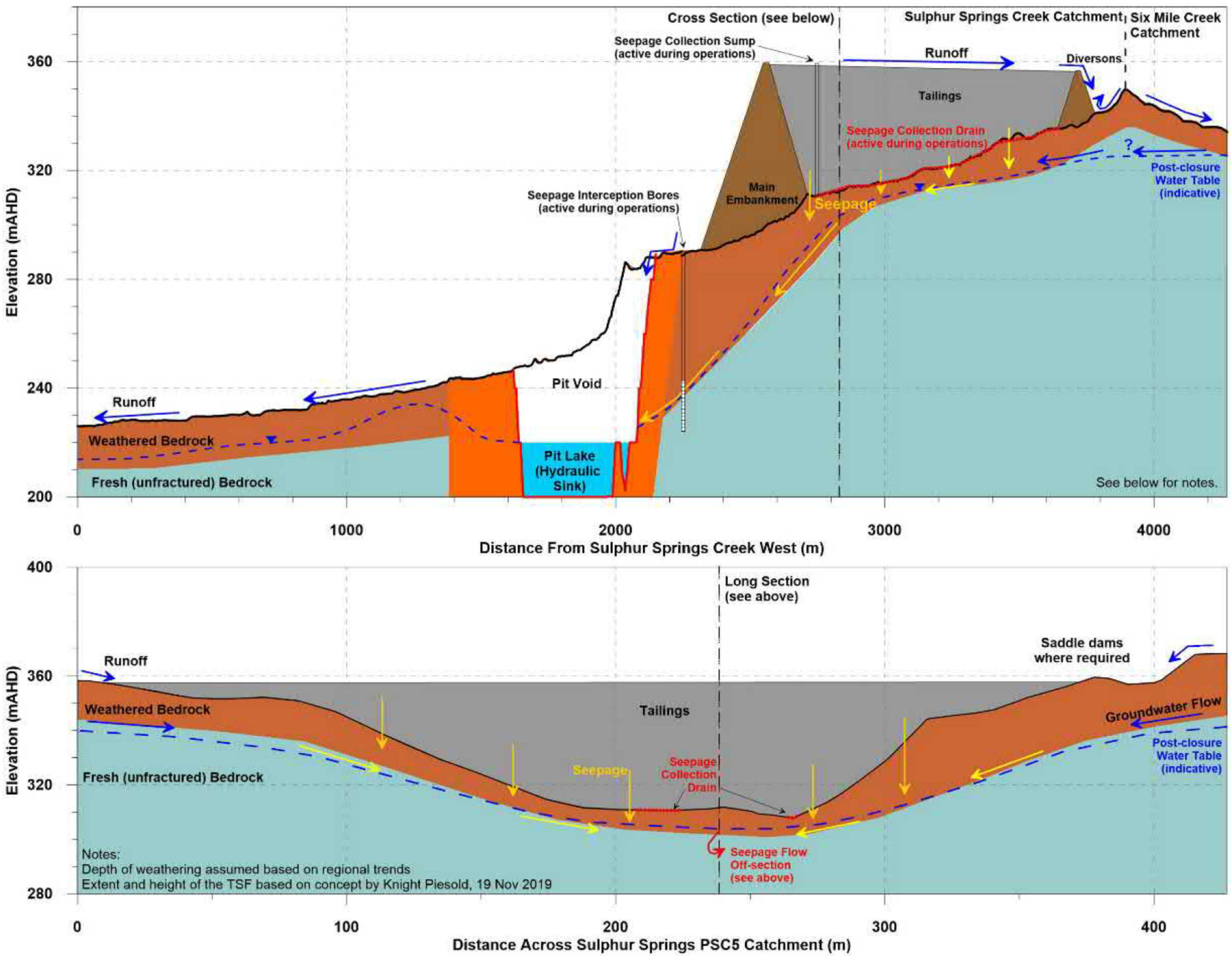
#### *9.3.3.1 Pit Lake Overtopping*

A conceptual model for the pit at closure is shown in Figure 19. Once mining is complete, the mine void will slowly fill. The rate of flooding will decrease once the water level reaches the pit floor (having first filled the underground mine voids) as the void volume per metre rise will increase significantly, and evaporation from the pit lake surface becomes significant (AECOM 2020a). Seepages from both the TSF and the portion of the WRD within the pit catchment area will drain to the water table and express from the pit walls below the valley floor. Modelling of the pit lake included the following inflows:

- Rainfall and surface water runoff. Annual rainfalls of 365 mm, 445 mm, 465 mm and 505 mm (compared with the current 30 year moving average for the site of 445 mm) were modelled to test the sensitivity of outcomes. Various catchment area scenarios were also modelled to inform modifications required to ensure the pit remains a hydraulic sink at closure. These modifications were outlined in Table 19.
- Native groundwater inflow, determined by hydrogeological modelling after dewatering ceases. Two inflow rates were considered: a base case and an alternative case (using lower host rock hydraulic conductivity and specific storage).
- Seepage from the TSF footprint. Seepage rates of 0%, 5% and 10% of annual rainfall were considered to test the sensitivity of outcomes.
- Seepage from the WRD footprint. A seepage rate of 10% of annual rainfall was assumed.

The pit lake level will fluctuate with the varying rates of groundwater, rainfall and surface runoff inputs and evaporative loss. The volume of surface runoff, governed by the amount of rainfall and upstream catchment area, is a dominant influence on the pit water balance and predicted equilibrium water level, where over the long term, inflows match evaporative losses. The predicted equilibrium and rainfall event-based pit lake levels have been modelled for a number of catchment scenarios, with the most applicable scenarios summarised in Table 24 (AECOM 2020d). With sub-catchment modifications proposed, the pit lake level remains below the point of surface discharge (1,245 mRL) under all ARI and PMP rainfall scenarios associated with the 20 and 30 moving average rainfalls. The residual risk of this impact is therefore considered to be low.

The mine pit lake water balance model will be refined during the operational phase of the mine as the geological and hydrogeochemical understanding of the pit and underground mine areas continually develops. Revisions of the model may lead to revisions in planned management measures and implementation at closure.




| | | | |
|---|---|---|---|
| Not to Scale<br>Original Size: A4 | Source: AECOM Sulphur Springs Project Groundwater Assessment 2020 | Venturex Resources Limited<br>Sulphur Springs Project | **Figure 19**<br>**Conceptual Groundwater Model for the Proposed Sulphur Springs Mine Area** |

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**Table 24: Simulated Pit Lake Water Levels for Average Annual Rainfall of 445 mm and 465 mm (Base Case)**

| Rainfall Scenario | Rainfall (mm) | Pit Water Level (m RL) with Pit Catchment Modified[1] | |
|---|---|---|---|
| | | Annual Rainfall (mm) | |
| | | 445 | 465 |
| Annual Rainfall | | 1,221 | 1,227 |
| 100 yr ARI 72 hr | 376 | 1,224 | 1,230 |
| 1,000 ARI 72 hr | 537 | 1,226 | 1,231 |
| PMP 1 hr | 590 | 1,226 | 1,232 |
| PMP 3 hr | 1,140 | 1,230 | 1,236 |
| PMP 24 hr | 1,530 | 1,233 | 1,239 |
| PMP 48 hr | 1,820 | 1,235 | 1,241 |
| PMP 72 hr | 2,300 | 1,239 | 1,244 |

Indicates seepage discharge from pit lake (> 1,235 m RL)

### 9.3.3.2 Pit Lake Seepage

The TSF is located wholly within the PSC5 sub-catchment of the mine pit. Existing groundwater discharging to Sulphur Springs Creek in the vicinity of the proposed pit is naturally sulphidic with pH values ranging from 2 to 4. Baseline surface and groundwater water quality in the vicinity of the mineralised area (both upstream and downstream) currently exceeds HMTVs for 95% protection of freshwater species (ANZECC and ARMCANZ 2000) for some metals. Existing salt-scarring along a 450 to 500 m stretch of Sulphur Springs Creek, immediately downgradient of the proposed pit provides an indication of the extent of existing and potential future groundwater discharges, should the pit become a groundwater seepage source. Based on this, it is anticipated that any surface expression of groundwater containing seepage that has originated from the TSF, WRD or pit area would extend to just upstream of CF1 (Figure 9). At closure:

- The drawdown cone around the mine void is predicted to extend under the entire TSF (Figure 15). Seepage from the TSF is expected to remain within the PSC5 catchment and migrate towards the mine void where it will be captured in a terminal sink.
- Seepage from the northern portion of the WRD will migrate towards the mine void where it will also be captured in a terminal sink. This volume will be very minor compared to other inflows to the pit lake.
- Water in the pit lake is predicted to become increasingly saline, with TDS values ranging from 5,259 mg/L (slightly saline) after 100 years to 26,609 mg/L (saline) after 1,000 years. Substantial (>50%) proportions of cadmium, nickel, selenium and zinc inputs are predicted to remain in solution following geochemical equilibration( AECOM 2020d).
- Simulated pit lake levels (Table 24) indicate that under only very extreme rainfall scenarios (well in excess of recorded daily and monthly rainfalls in the region) the water level could rise above the point where groundwater seepage occurs 1,235 mRL). The likelihood of these events is estimated to be in the order of 1 in 10 million years (A, 2020d). In such a circumstance the pit lake could then become a groundwater source for a period, pushing contained water into the Sulphur Springs Creek catchment, until water levels recede to below 1,235 mRL.
- The consequences of this seepage are likely to be limited to the zone between the pit and CF1 which is currently exposed to natural acidic discharge.

Overall, the residual risk of this impact is considered to be low. To ensure potential impacts from seepage are appropriately managed, the final design criteria will be informed by the results of water monitoring during operations. These criteria will be developed to minimise adverse environmental changes.

#### 9.3.4 Insufficient NAF Material for PAF Encapsulation

The need for effective encapsulation of PAF waste rock and tailings material requires ready availability of adequate volumes of NAF mine waste rock. The current mine plan material balance indicates that overall volumes of NAF material exceed PAF material by a factor of four which is sufficient for encapsulation and cover requirements.

Venturex is cognisant of the risk posed by premature closure or suspension of operations on the availability of sufficient volumes of NAF material to cover exposed PAF. The risk is diminished by the effective completion of the mine pit by year 5 of mining at which time the majority of waste rock (NAF and PAF) has been mined. Within this period mine scheduling will ensure that at any time sufficient NAF is available to cover the extent of exposed PAF material.

The feasibility of staging the closure of the TSF by partitioning tails deposition and potentially completing and covering cells early in the operations phase continues to be investigated. This measure would serve to reduce the risk of unplanned closure. This option will be detailed in an updated MCP to be submitted to DMIRS for approval should it prove implementable, following the completion of site investigations.

#### 9.3.5 Underestimation of Closure Costs and an Inappropriate Closure Provision

Underestimation of closure costs could lead to inadequate financial provisioning for complete and effective mine closure.

As part of its financial risk management, Venturex intends to maintain sufficient liquidity to meet its obligations as they fall due, under normal and stressed conditions.

Venturex will regularly review its closure liability, which will be progressively informed by actual site experience with the costs and effectiveness of rehabilitation undertaken during the operations phase.

Once the Project commences, Venturex will maintain financial provisions (liabilities of uncertain timing or amount) sufficient to cover incurred closure obligations, in a manner consistent with Australian Accounting Standards Board (AASB) Standard 137 *Provisions, Contingent Liabilities and Contingent Assets*. The closure provisions will be shown on the Venturex financial statement, disclosed as a requirement of its public listing.

#### 9.3.6 Ineffective Safety Measures, Resulting in Injury or Death to Workers or the General Public

The safety of both company workers and the general public remains a primary concern at all mine sites and is considered paramount during all phases of the mine life. All closure planning and implementation activities have to adhere to the strictest OHS standards that meet Australian Mining Industry Best Practice standards. Access to the mine site will be strictly controlled throughout the closure implementation period and appropriate controls put in place post closure.

# 10. CLOSURE IMPLEMENTATION

## 10.1 Closure Management During Operations

### 10.1.1 Soils and Growth Medium

During Project development, vegetation and topsoil (growth medium) resources will be stripped from the Project footprint and appropriately stockpiled to minimise rehandling costs at closure. Generally, these resources will be placed at the periphery of the areas from which they were stripped, or close to where they will be finally deployed. These resources will be protected from use, disturbance, contamination or erosion over the life of the operations. Growth medium stockpiles will be no more than 2 m high, to preserve inherent nutrients and seed bank.

Due to the rugged terrain and high proportion of coarse material present in Project area soils (Section 7.4), growth medium recovery from some disturbance areas, such as the pit, may be limited. A comprehensive site reclamation materials balance will be undertaken at the time of construction so as to prioritise material placement to the most important areas. It may be necessary, should there be a significant shortfall of regrowth material, to source additional material from the borrow pit and processing plant areas. This material will be stockpiled separately according to physical and chemical characteristics (Table 7), in a way such that handling costs will be minimised, and may be seeded with an appropriate seed mix as soon as possible, to establish a supplementary seed bank over the life of operations.

### 10.1.2 Seed

Venturex will collect local native seed to supplement the seed bank in growth medium stockpiles. The quantity available may vary from year to year, depending on rainfall and drought. The most suitable and efficient seed mixes to collect will be determined from studies, and the quantities determined from estimates of viable seed bank established in growth medium stockpiles. Different seed mixes may be selected for different natural and artificial landforms, depending on closure criteria. Seed will be treated as a valuable asset and stored in appropriate climate-controlled container.

### 10.1.3 Rehabilitation Trials and Progressive Rehabilitation

Most land areas disturbed for Project development and operations will remain in use for the life of the Project and will generally not be available for progressive rehabilitation prior to closure. At the completion of Project construction, there may be opportunity to rehabilitate certain laydown yards and access roads established purely for construction purposes. There may also be some limited opportunities to further consolidate and rehabilitate laydown areas and other disturbances over the life of operations. Exploration or resource definition disturbances will generally be reinstated progressively over the life of operations, in accordance with exploration approvals, and are generally considered separate to this MCP. Any near-mine exploration disturbances remaining at time of closure will automatically be dealt with as part of closure activities.

The possible staged completion of the TSF and establishment of some final slopes on the WRD may also provide opportunities for early rehabilitation during the operations phase. These initiatives will be described in an updated MCP should current studies find they are practicable.

### 10.1.4 Additional Studies

A number of additional studies/assessments will be considered during the detailed design and operational phase of the Project with the aim of providing additional information to refine closure design. These are detailed in Table 25.

**Table 25: Possible Additional Closure Planning Studies/Assessments**

| Item | Possible Additional Studies | Comment |
|---|---|---|
| Geochemical Characterisation Studies | Further whole rock/total element analysis of representative samples of the widest compositional variation of potentially mineable hanging wall and footwall lithologies. Increased number of analytes to include Tl, Sc, Ce, Y, In. | The existing dataset is adequate for assessing AMD risk, waste type by lithology and degree of weathering. Future exploration drilling programs should include multi-element analysis of representative samples of each lithology to consolidate the value of the database. |
| | Maintain a mass balance estimate of the relative proportions of PAF and NAF mine waste material throughout the mine life. | Development of the sulphur block model using total sulphur cut-off grades will provide a reliable estimate of volumes of NAF and PAF waste rock. |
| | Update pit lake model as leachate compositions from TSF become available. | A standard operational commitment. |
| Water Models | Update water balance and solute transport models to include potential reactions within the TSF, WRD and pit as knowledge improves during the operational phase. | A standard operational commitment as these models can realistically only be refined to the required confidence levels once substantially more site-specific operational data has been collected. |
| TSF Cover | Undertake further cover design evaluation that includes pre-closure cover trials. This will better define 'nominal' thickness of topsoil layer and expected properties of clay layers | Closure studies (during operational phase of Project) will inform this item. Results to be progressively included in updated Mine Closure Plans. |
| Tailings Deposition | Investigate optimum tailings deposition methods to provide for maximum water recovery, maximise storage volumes, limit oxidation and early rehabilitation. | Investigations to seek to take advantage of natural slopes for tailings drainage and test feasibility of compartmentalising the TSF valley without significant loss of storage volume to internal embankments. |
| Tailings Deposition | Investigate use of polymer based flocculant to optimise water recovery, consolidation time and steepen beach angles. | Polymer may lead to more rapid water release and tailings consolidation enabling earlier rehabilitation |
| Pit Water Balance | Investigate feasibility of diverting runoff from pit sub-catchments PSC4 and PSC6 away from the mine pit | Presents an opportunity to reduce the already unlikely risk of the pit lake filling to the point of discharge. |
| Early Rehabilitation | Investigate the practicability of establishing final outer slopes suitable for rehabilitation in years 1 to 5 of operations. | The majority of waste rock movement occurs in the first four years and sophisticated scheduling my provide an opportunity for direct placement and early rehabilitation. |
| Mine Pit | Investigate feasibility of backfilling the pit void without compromising ability to act as a perpetual groundwater sink. | Presents an opportunity for tailings and minimising open water surface subject to safety management for underground mine |
| Environmental Impacts | Revise ecological risk assessments as additional site data becomes available, particularly in regard to groundwater and surface water monitoring within Sulphur Springs catchment. | Operational monitoring during construction and operation of the various mine landforms/structures will provide adequate data for a definitive ERA for closure planning. |

## 10.2 Planned Closure

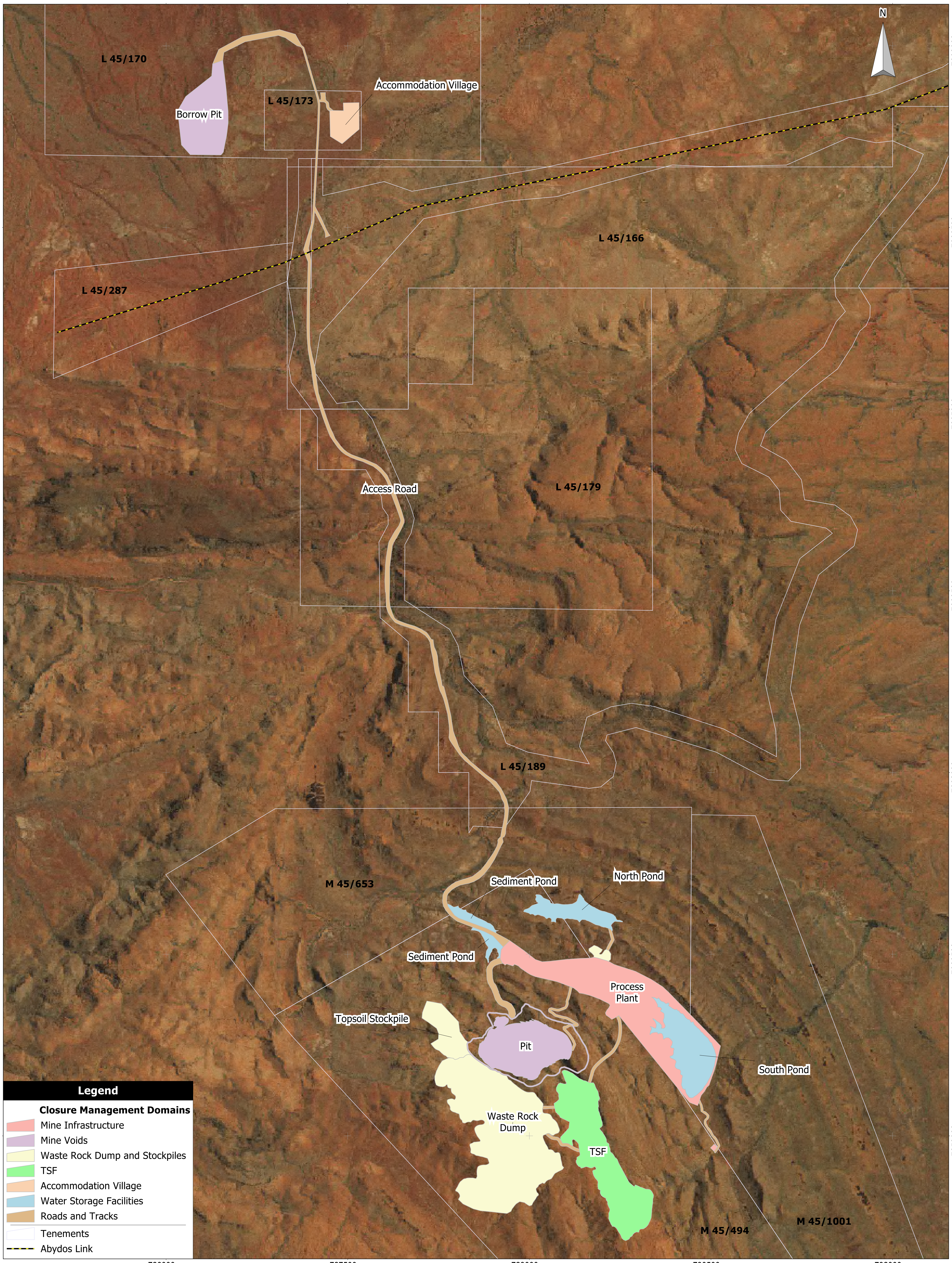
### 10.2.1 Overview

The estimated LOM is 10 years. For closure management purposes, the features or areas of a minesite have been broken down into groups (referred to by DMIRS as "domains") based on the types of decommissioning and rehabilitation works required at closure. Domains for the Sulphur Springs site are summarised in Table 26 and shown on Figure 20. Expected closure tasks for each domain are summarised in the following sections, together with general measures or prescriptions. Venturex will prepare a detailed plan for implementation once mining has commenced which will be progressively refined and updated during the operations phase.

**Table 26: Closure Management Domains**

| Domain | Main Elements |
|---|---|
| **Mine Voids** | |
| Open pit and underground mine | Open pit, boxcut, haul roads, dewatering infrastructure, safety and abandonment bunds. |
| Borrow pits | Construction material borrow pits |
| **WRD, Stockpile and ROM Landforms** | |
| Waste Rock Dumps | WRD |
| Temporary Stockpiles | Ore stockpiles |
| Regrowth Medium Stockpiles | Regrowth material stockpiles |
| ROM Pad | Run of Mine pad and possibly mine ore pads |
| **TSF** | |
| Tailings storage facility | Tailings surface and outer embankments. |
| **Mine Infrastructure** | |
| Processing plant, power station and mine surface facilities | Concentrator, bulk reagent stores, concentrate shed and load-out facility, workshops, washdown bays, bulk diesel tanks, offices and showers, Plant WWTP, ponds and irrigation field, parking and laydown areas, stormwater drain and ponds, explosives magazine, generators, LNG vacuum insulated vessels, bulk diesel tank and bund, day diesel tank, waste oil tank, washdown bay, control room, power lines, access and haul road, tailings and water lines. |
| **Accommodation Village** | |
| Camp | Accommodation units, mess, kitchen, offices, laundries, gardens, recreation facilities and other buildings |
| WWTP | Village WWTP, ponds and irrigation field |
| **Water Management infrastructure** | |
| Surface water infrastructure | Runoff diversion pond, sedimentation ponds and associated infrastructure. |
| Groundwater infrastructure | South Pond and North Pond, production bores, pumps and pipes, tanks/ponds, monitoring bores, reverse osmosis plant |
| **Roads** | |
| Roads | Site access road |
| Compacted Roads | Haul roads |
| Unsealed Roads | Site roads and tracks not included in above areas |

| Domain | Main Elements |
|---|---|
| **Service Corridors** | |
| Water services and distribution | Water distribution infrastructure (Potable water, Fire water, Wastewater and Process water circuits) |
| Power distribution | Power lines and transmission substations |
| Telecommunications | Telecommunication lines and infrastructure |
| **All Other Disturbed Areas** | |
| Other disturbed land | Magazine and emulsions compound and any other disturbed land. |
| Landfills | Landfills and waste collection laydowns |

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Grid: MGA94(50)
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Venturex Resources Limited
Sulphur Springs Project

**Figure 20**

**Closure Management Domains**

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W:\Venturex Resources\Sulphur Springs\Projects\2018 Mine Closure Plan\Drawings\Sulphur Springs MCP (from ERD).map 24/01/2020 F20 Closure Management Domains Layout 2

#### 10.2.2 Mine Voids

The primary considerations for closure of the pit and underground include reducing the potential for access and controlling surface water flows into the pit.

As far as practicable, Venturex will decommission the underground mine progressively as it nears completion, to avoid maintaining services (power, dewatering and ventilation) for a long time after ore production ceases. At completion, mining will wind down; remaining economically salvageable parts, equipment or infrastructure will be progressively removed from the mine. Mine dewatering will continue as long as required to provide process water supply and allow a safe retreat from the mine workings.

When access to the decline is no longer required, the portal will be blocked with waste rock. A security gate will then be placed across the portal and danger signs installed. Once access to the open pit is no longer required, the safety bund will be closed off across the pit ramp and danger signs will be installed. The mine, including the lower portion of the pit, will be allowed to fill with water.

The current closure strategy involves modifying the pit catchment area to ensure the pit lake does not overflow. The final TSF surface will be shaped so as to divert the majority of surface water from this sub-catchment into the Minnieritchie Creek and/or Six Mile Creek catchment areas.

Results of monitoring prior to construction and during operations will inform further review and possible refinement of closure designs and will be included in future iterations of the MCP.

Where possible, borrow pits will be progressively rehabilitated during the mine life. Any borrow pit sites used to source additional cover materials for closure will be rehabilitated following final excavation of materials. This will involve re-contouring slope batters to 10 degrees or less to make safe, spreading with regrowth material sourced from adjacent to the pits, deep contour ripping and revegetation.

Suitable elements of the mining fleet (which may include small dozers, graders, and light vehicles) will be directed to rehabilitation and decommissioning works where practicable after mining finishes. Much of the underground fleet is not likely to be suitable or efficient for closure works and will be demobilised.

#### 10.2.3 WRD, Stockpiles and ROM Landforms

##### 10.2.3.1 Waste Rock Dump

The WRD will infill the valley southeast of the pit and the valley walls will form most outer batters of the final landform. Over the Project life, waste rock management practices will ensure PAF waste requiring permanent surface storage is suitably encapsulated within the WRD (Table 27). This includes placement of a 5 m thick layer of NAF waste rock over any PAF encapsulation areas, prior to shaping of the final landform at closure (Figure 16).

**Table 27: Estimated Pit Waste Volumes**

| Mine Year | Cumulative PAF Mined at End of Period ($m^3$) | Cumulative NAF Mined at End of Period[1] ($m^3$) |
|---|---|---|
| 1 | 698,098 | 7,518,840 |
| 2 | 2,879,680 | 13,426,531 |
| 3 | 3,828,505 | 17,597,175 |
| 4 | 4,222,094 | 17,893,944 |

[1] Note: Approximately 885,000 $m^3$ of this NAF will be used for construction purposes and will not be stored in the WRD

Shaping will be required for those small sections of the WRD perimeter that are not bound by the valley wall and here, waste rock batters will be pushed down to a single slope at a stable angle (approximately 18 degrees or 1V:3H gradient). A thin layer of growth medium will be spread on the outer waste rock batters, to provide niches for vegetation establishment, and promote vegetation cover that reduces the visual impact of the landform.

As the end of pit operation approaches, waste rock disposal will be managed to leave the top of the dump gently inward-sloping, with at least 1.5 m high competent rock crest bunds to prevent runoff onto the outer batters, minimising the potential for erosion. Excess surface runoff from the upper surface will be directed onto the western ridge where it will be allowed to follow the natural contour and existing drainage line to discharge into the Six Mile Creek tributaries. Stockpiled growth medium and vegetation will be spread on top of the landform, to an appropriate depth to support revegetation objectives.

A sediment containment bund will be formed around the toe of the landform, incorporating spillways and settling basins as appropriate, using competent waste rock and overburden material. Drains, bunds and ponds constructed to manage surface water and sediment loads during operations will be rehabilitated where no longer required. Any storm runoff that might occur from the single slope northern batter will be allowed to discharge into the mine pit with any sediment discharge contained within the pit void.

Temporary fencing will be deployed as necessary to minimise stock and macro fauna accessing newly rehabilitated areas.

#### 10.2.3.2 Stockpiles

All existing ore and regrowth medium stockpiles are to be processed or used during rehabilitation activities. The remaining footprint will be re-contoured to restore the natural surface drainage as far as practicable, deep ripped to promote infiltration and stockpiled regrowth material and vegetation spread to promote revegetation.

#### 10.2.3.3 ROM Pad

Once all ore stockpiles are depleted the upper surface area of the landform will be skimmed for treatment to ensure that all ore dust is processed. The landform will then be reshaped to be water shedding with outer batters that do not exceed 1:3 grades (approximately 18 degrees or 1V:3H gradient). All disturbed surfaces are to be deep ripped on the contour and seeded.

### 10.2.4 Tailings Storage

The primary goal for the TSF closure design is to create a stable landform with a final surface that has the following characteristics:

- Water shedding to the south with no potential ponding.
- A spillway(s) located at the lowest relief to facilitate water shedding with minimal erosion.
- Cover design of minimum 2 metres thickness, incorporating a low permeability layer to minimise infiltration to tailings, and is capable of sustaining vegetation.

The TSF will remain operational throughout the Project life and in the later years it will receive flushing water and sediments generated during decommissioning of the processing plant. When the structure is no longer required for this or other water management purposes, the tailings discharge and return water pipelines will be flushed to the TSF and cut up and removed for disposal in the pit, or if cost-effective, shredded and collected by a HDPE recycler. The decant pond will be drained into the water treatment plant.

The embankment underdrainage system will remain operational to continue draining during, and for a period after, closure. Rehabilitation works on the TSF will finalise after decommissioning once there has been adequate drying and consolidation of the tailings to enable machinery traffic.

In general, the conceptual cover system design for the Sulphur Springs TSF focuses on minimising the potential for oxygen ingress and rainfall infiltration to the tailings mass and consequently seepage to the mine pit. The final landform design is likely to utilise a combination water shedding, and moisture store and release concepts (which in general is more robust than simply applying one of these two concepts).

The water shedding concept is designed for less frequent high intensity rainfall events, where rainfall exceeds infiltration rates excess water (runoff) must be shed with minimal erosion risk. The moisture store-and-release concept is more applicable for less intense rainfall events where a greater proportion of incident rainfall infiltrates and is stored within the cover profile. This will consist of a low permeability layer (clay or other) under a well graded NAF growth medium layer.

The low permeability layer at the base of the cover system will limit percolation/seepage to the tailings, promote drainage from the upper profile off the TSF and limit the upward migration of contaminants from the tailings. The well graded NAF growth medium layer is designed to provide moisture retention to promote the store-and-release function via evaporation and evapotranspiration and the establishment of vegetation through improved water availability. A nominal stripped and stockpiled growth medium layer above will serve to provide a seedbank, increase plant available water during seed germination, and provide nutrients during initial establishment. It may be possible that modelling (based on site specific material characteristics and final growth medium thicknesses) can demonstrate that a low permeability layer (compacted clay liner or other) alone in combination with a suitable growth medium per engineering design (i.e. enhanced store and release cover) is sufficient to attain target performance objectives.

As the Project progresses, Venturex will undertake the following investigations and provide updates in subsequent iterations of the MCP:

- Determine acceptable rates of seepage into the surrounding environment in order to refine nett percolation (NP) targets.
- Use refined NP targets to determine if vegetation will be required to perform a key functional role in transpiring water from the cover system.
- Conduct further materials characterisation and schedule and block model refinements to confirm the availability of onsite store and release material sources, quantities and volumes for the growth medium and compacted clay layers.
- Develop long term climatic data set for cover design with consideration of possible/probable changes in long term climate change.
- Determine the required cover system slope based on design criteria to promote positive drainage.

Selection of species for any revegetation strategy on the TSF surface will consider the risk of penetration of the low permeability cover base by plant roots. The current proposed growth medium layer thickness has been determined to account for the possibility that deeper rooted species (e.g. *Eucalyptus* and *Acacia*) may establish on the cover system through natural seed propagation (OKC 2017).

Temporary fencing will be deployed as necessary to minimise stock and macro fauna accessing newly rehabilitated areas.

#### 10.2.5 Mine Infrastructure

Primary considerations for closure of built infrastructure include potential contaminated sites, rehabilitation of disturbance areas and post-mining surface water drainage patterns.

Ore processing will continue until ore stockpiles have been exhausted. When complete, de-commissioning works will begin on the processing plant and ancillary infrastructure. The concentrator circuit will be flushed with water and the slurry/water mix discharged to the TSF.

Infrastructure will be cleaned down. All economically salvageable structures and parts will be dismantled and set aside for collection. The remainder will be demolished. Scrap metal and other economically recyclable materials from demolition will be set aside for collection by a recycler. Any remaining materials that are not economically salvageable or recyclable will be disposed of in appropriate landfills or buried at the base of the pit. Laydown yards will be organised to support the management and segregation of materials, and progressively consolidated and rehabilitated as materials are taken from site or disposed of.

Facilities such as workshops, washdown and hydrocarbon storage, and services such as power and water, will be retained as required to support the decommissioning and rehabilitation fleets, and progressively decommissioned as work winds down. Temporary minor facilities, such as transportable workshops, fuel tanks and generators, will be brought in if required to service requirements once major facilities are decommissioned.

Electrical, water, air and other services will be safely terminated. Buried services will be located and flagged to ensure that they do not present a hazard to closure works. HDPE pipelines, including tailings and return water lines, water supply lines and dewatering lines, will be cut up and removed for recycling, if economic, or disposal.

Remaining bulk quantities of process reagents will be sent off-site for use elsewhere, returned to the supplier or for licensed disposal. Waste reagents and hydrocarbons, or highly contaminated materials unsuitable for remediation and/or disposal on-site, will be segregated for collection and disposal off-site by a licensed contractor.

Areas of concern identified in preliminary contaminated site investigations will be investigated in detail. Contaminated soil will be remediated or encapsulated in place or removed for encapsulation within the WRD. Highly contaminated material not suitable for encapsulation on site will be segregated for collection and disposal by a licensed contractor.

Drains and bunds constructed to direct surface water around infrastructure such as the processing plant will be rehabilitated where no longer required. Drains that are to remain as part of post-closure surface water management will be modified, re-shaped and armoured as appropriate to remain stable over the long term.

All disturbed areas, aside from the mining landforms and any infrastructure transferred to third parties (e.g. camps), will be re-contoured to restore the natural surface drainage as far as practicable. Stockpiled growth medium and vegetation will be re-spread over disturbed areas, to prevent erosion and promote revegetation, and the areas ripped to an appropriate depth to promote rain infiltration. Where necessary, an appropriate seed mix of representative species for the natural landforms will be applied to reinstated disturbances.

The package WWTP will be one of the last items to be removed from site. The plant will be flushed and cleaned down and accumulated sludges will be disposed of by an appropriate contractor. The WWTP will be returned to the supplier or sold and any supporting infrastructure will be demolished for disposal. WWTP irrigation areas will be left at closure for any accumulated nutrients and salts to dissipate.

### 10.2.6 Accommodation Village

Some accommodation units, basic kitchen and mess facilities, power, water, sewage treatment, and other services will be retained as necessary to support the decommissioning and rehabilitation crews, and progressively closed once no longer needed. The accommodation village is likely to be the last domain to be closed, though workers for the very final stages of closure works may have to be housed at a nearby mine or exploration camp and commute daily.

To close the accommodation village and other ancillary buildings, except where binding arrangements are in place for transfer of facilities to a third party, Venturex will:

- Remove furniture (beds, chairs, etc.) and equipment (washing machines, kitchen appliances, etc.) for salvage or disposal and clean up general rubbish for disposal in the landfill.

- Terminate and make safe water, power and other services. Below-ground services will be terminated below ground level and left in place.
- Progressively disconnect and load out accommodation units and other demountable buildings for return to the leasing company, or sale. Where buildings cannot be returned or sold, they will be demolished for disposal.
- Flush and clean down the package WWTP and arrange for accumulated sludges to be disposed of by an appropriate contractor. The WWTP will be returned to the supplier or sold and any supporting infrastructure will be demolished for disposal. WWTP irrigation areas will be left at closure for any accumulated nutrients and salts to dissipate.
- Break up concrete slabs and footings up to 1 m below ground level. Broken-up concrete will be buried in place or in nearby disposal pits.
- Re-contour the disturbed footprint to restore the natural surface drainage as far as practicable, deep rip to promote infiltration, and respread stockpiled growth medium and vegetation to promote revegetation. Where possible, existing vegetation and regrowth will be retained through decommissioning and rehabilitation works.

Closure of the accommodation village presents no unconventional challenges, and no particular knowledge gaps are identified at this stage. Monitoring of progressively rehabilitated areas over the LOM should confirm that disturbed areas can be adequately rehabilitated by conventional methods or identify where additional measures such as supplementary seeding may be required.

### 10.2.7 Water Management Infrastructure

#### 10.2.7.1 Surface Water Infrastructures

All surface water infrastructure not required for post closure drainage control is to be decommissioned, dismantled and removed so that the land surface can be fully rehabilitated. Sediment ponds/traps/sumps are to be cleaned of any sediment and contaminated material prior to ripping in preparation for re-vegetation.

Drainage structures that are to remain need to meet 1:10 year 24 hour storm conditions. All surface impoundments are to be left in a structurally sound and maintenance-free state, with any spillway designed to 1:1,000-year 72-hour ARI. All structures are to be designed to be safe, with minimal ongoing maintenance requirements.

#### 10.2.7.2 Groundwater Infrastructure

Groundwater abstraction bores and pipelines will be retained as necessary to support decommissioning and rehabilitation activities, in particular to supply potable / village use, dust suppression, and washdown, and progressively closed once no longer needed. Temporary minor facilities, such as transportable water tanks, may be brought in if required as works draw to a close.

To close the water services and distribution infrastructure, except where binding arrangements are in place for transfer of water supply infrastructure to a third party, Venturex will:

- Pull up bore pumps for salvage or disposal.
- Decommission generators or fuel tanks for salvage or disposal; clean out containment bunds and treat or appropriately dispose of contaminated soil; remove and dispose of bund liners.
- Cut up and remove HDPE pipelines for disposal in the mining void, or if cost-effective, shredding and collection by an HDPE recycler.
- Push in any pipeline containment bunds and scour pits.
- Fully decommission bores in accordance with DWER standards.

Storage/evaporation ponds are to be decommissioned, dismantled and removed so that the land surface can be fully rehabilitated. Ponds are to be cleaned of any sediment and contaminated material prior to contour re-shaping to replicate the local topography and ripping in preparation for re-vegetation.

Closure of the bores and evaporation ponds presents no unconventional challenges, and no particular knowledge gaps are identified at this stage.

#### 10.2.8 Roads

Roads and service corridors will be retained as required during the decommissioning and rehabilitation stages and progressively rehabilitated as they are no longer required. A track along the site access road route will be maintained to provide access for post-closure monitoring and maintenance, including ongoing maintenance of engineered structures.

To close site roads and service corridors, except where binding arrangements are in place for transfer of liabilities, Venturex will:

- Remove all signage, fencing, shade structures, traffic barriers, etc.
- Remove culverts and reinstate any drainage line crossings, where appropriate, and re-contour the road or service corridor alignment to restore the natural surface drainage as far as practicable.
- Deep rip to promote infiltration (deeper in areas of heavy traffic and/or high compaction) and respread windrowed growth medium and vegetation to promote revegetation.
- Construct substantial bunds across the entry to the rehabilitated corridor to prevent vehicle access.
- Place signs showing “TRACK UNDER REHABILITATION – DO NOT USE”, or similar.

The closure of site roads and service corridors presents no unconventional challenges, and no particular knowledge gaps are identified at this stage. Monitoring of progressively rehabilitated areas over the LOM should confirm that disturbed areas can be adequately rehabilitated by conventional methods or identify where additional measures such as supplementary seeding may be required.

#### *10.2.9* Other Disturbed Land

All other disturbed areas are to be cleared of rubbish, infrastructure, machinery, etc. prior to re-contouring to ensure unimpeded surface drainage. All surface to be deep ripped and seeded.

### 10.3 Suspended Operations

A variety of unexpected events, such as a ground failure in the mine, a safety incident, or failure of plant, infrastructure or supply lines may require a temporary suspension of operations. Such suspensions will tend to be relatively brief in the LOM, and Venturex will control such hazards as far as possible to reduce the likelihood of interruptions to operations.

Other circumstances, such as adverse commodity market conditions, or a combination of circumstances, may require a prolonged suspension of operations, before the end of the scheduled LOM. In these circumstances, the site would be placed into care and maintenance. In this event a detailed Care and Maintenance Plan will be prepared, based on the current MCP, and submitted to DMIRS within three months of formal notification to regulators or at such other time as specified by DMIRS. The primary aims of this plan would be to protect the environment, public safety and Project assets. If it appears that a prolonged suspension may be necessary, Venturex will:

- Conduct safety and environmental reviews of the site and prepare a plan to address any particular hazards identified for suspension.
- Assess to what extent the open pit mine can be allowed to fill with water and the amount of dewatering required to maintain water below an acceptable level. Any excess mine water that

cannot be held in storage ponds or consumed by processing or dust suppression during suspension will be quantified and options for disposal such as evaporation via the surface of the TSF will be determined.

In the event of a prolonged or indefinite suspension, Venturex will:

- Notify DMIRS as required under MSIR, and other regulators as appropriate, and provide details of arrangements for the care and maintenance of the site.
- Move all mobile or transportable plant and equipment out of the mine, to be cleaned down, made safe, and parked up and immobilised at a suitable location on the surface.
- Place barriers across the entrance to the underground to prevent inadvertent access.
- Close the pit safety bund at the top of the access ramp, unless ongoing access is required for dewatering or other purposes.
- Process ore stockpiles, and transport any product off-site, as far as practicable. Any remaining stockpiles considered to have AMD potential to be placed within the mine pit. All other stockpiles will be left stable and bunded off if necessary, to prevent stormwater contamination.
- Compact material in any active PAF cells on the WRD and cover with a three metre NAF layer. Ensure that water shedding covers are installed over all PAF cells.
- Flush reagent tanks, plant, and tailings lines with water and discharge to the TSF. Clean down the plant, conveyors, and storage and handling areas for concentrate, product and reagents.
- Return bulk quantities of reagents to the supplier or another site, if possible, and reduce stores of lubricants, fuels and chemicals to the minimum required for care and maintenance.
- Shut down and make safe services, including power and water supply, except where required for care and maintenance.
- Send rented equipment off hire, except where required for care and maintenance.
- Demobilise most of the site personnel, to leave a small care and maintenance crew.
- Install fences with locked gates if necessary, to prevent unauthorised access to mine property and equipment.

During suspension, Venturex will:

- Maintain adequate emergency and other support services for the care and maintenance crew.
- Continue mine dewatering, and monitor any discharge, if necessary.
- Inspect any active dewatering or other saline water lines and ponds for leaks, and repair where necessary.
- Inspect and maintain surface water management infrastructure.
- Inspect the TSF to check that adequate stormwater freeboard and embankment integrity is maintained.
- Take measures to limit oxygen ingress to the tailings mass and suppress dust from the tailings surface if necessary, including use of water sprays and/or application of a binding agent.
- Maintain TSF embankment underdrainage recovery and return to the decant for evaporation and continue to monitor groundwater for indications of adverse seepage.
- Inspect the TSF and WRD to identify any unacceptable erosion or sediment transport and carry out remedial or containment earthworks if necessary.
- Care for and maintain the plant, equipment, buildings, bores, access roads and other infrastructure, to protect the value of the assets and facilitate an eventual return to operations

- Continue monitoring and reporting to relevant regulators as required under current licences and permits.

In the event of any suspension of or return to operations, Venturex will notify DMIRS-RSB and provide all required site plans and other information, as required under the MSIR (Section 3.5.2).

## 10.4 Unplanned Closure

A variety or combination of exceptional circumstances, such as a particularly severe pit wall failure, error in resource modelling or extraordinarily poor and prolonged market conditions, with little or no prospect of recovery, may sometimes cause mines to close early and well before the expected end of the LOM.

The impacts of early, unplanned closure at Sulphur Springs would depend largely on the stage of mine development, in particular the mining void or underground. Principal risks would include:

- PAF waste rock left uncovered on the WRD. These materials will be preferentially returned to the mining void where practical. If materials are to remain on the surface, additional mining may be required to obtain a sufficient cover of competent NAF waste rock, reshaping the weathered material and covering with a thick layer of stockpiled regrowth material.
- Shortfall of store and release cover material to cover tailings in the TSF: additional mining may be required to obtain a sufficient cover of competent benign waste rock.
- Unevenly developed tailings surface: additional mechanical shaping may be required to form an even, gently sloping surface suitable for rehabilitation, although this risk can be mitigated by careful management of deposition to form even tailings beaches from the commencement of operations.
- Insufficient tailings fill to permit water shedding cover design: The PSC5 catchment is progressively filled with tailings over the course of the mine life. In the early years when the fill volumes are relatively small, the merits of backfilling the pit with tails (and waste rock) will be compared against re-contouring the catchment with waste rock from the adjacent WRD (done in a way to maintain the water diversion function of the WRD).
- An incomplete pit void, that may form a final pit lake with different hydrological characteristics to those modelled for planned closure.

Whilst Venturex considers the likelihood of such circumstances extremely low, it will incorporate appropriate risk provisions for premature closure and the additional works that may be entailed when reviewing and setting current closure provisions (Section 12). In most other substantial respects, the decommissioning and rehabilitation works required for unplanned closure will be the same as for planned closure. Venturex will notify DMIRS-RSB, DMIRS-EB and other relevant agencies in the event of any decision to close the mine substantially ahead of the expected LOM.

### 10.4.1 Conceptual Unplanned Closure Schedule

A conceptual schedule of closure tasks has been developed in the event that unplanned closure occurred during Years 1 to 4 and is presented in Table 28. The tasks are subject to final Project designs and further investigations and will be updated in the MCP to be submitted to DMIRS with a Mining Proposal for approval.

**Table 28: Conceptual Unplanned Closure Task Schedule**

| Year | Landform | Approximate Area | Closure Task |
|---|---|---|---|
| 1 | TSF | 10.7 ha | • Investigate merit of returning tailings to the mine void.<br>• Reshape tailings surface to create water shedding profile that could include an engineered discharge channel.<br>• Drain and cover as per Section 10.2.4. Subject to final TSF design, this will require:<br>– 21,350 $m^3$ of material for Zone A sub-base (to be sourced from site borrow pit).<br>– 16,010 $m^3$ of material for liner protection layer (if required). Material likely to be sourced from site, subject to further soil assessment during detailed design phase, or sourced from offsite at an approximate cost of \$40/$m^3$)<br>– 213,520 $m^3$ NAF sourced from the WRD. |
| | WRD | 40.5 ha | • Investigate merit of returning waste rock to the mine void.<br>• Cover exposed PAF material in encapsulation cells with a 10 m layer of NAF waste rock (will require approximately 576,000 $m^3$ of NAF waste rock sourced from the WRD).<br>• Close as per Section 10.2.3 including reshaping to direct surface water away from the pit. |
| | Pit | - | • Construct pit water diversion measures (including reshaping TSF and/or WRD sub-catchments, subject to available waste rock) to redirect surface water from the catchment upstream of the pit.<br>• Manage as per Section 10.2.2. |

| Year | Landform | Approximate Area | Closure Task |
|---|---|---|---|
| 2 | TSF | 17.6 ha | • Reshape tailings surface to create water shedding profile with construction of simple engineered discharge channel.<br>• Drain and cover as per Section 10.2.4. Subject to final TSF design, this will require:<br>– 35,120 m³ of material for Zone A sub-base (to be sourced from site borrow pit).<br>– 26,340 m³ of material for liner protection layer (likely to be sourced from site, subject to further soil assessment during detailed design phase, or sourced from offsite at an approximate cost of $40/m³)<br>– 351,160 m³ NAF waste rock sourced from the WRD. |
| | WRD | 64.7 ha | • Cover exposed PAF material in encapsulation cells with a 10 m layer of NAF waste rock (will require approximately 1,265,130 m³ of NAF waste rock sourced from the WRD).<br>• Close as per Section 10.2.3 including reshaping to direct surface water away from the pit. |
| | Pit | - | • Construct pit water diversion measures (including reshaping TSF and WRD sub-catchments or both subject to available waste rock) to redirect surface water from the catchment upstream of the pit.<br>• Manage as per Section 10.2.2. |
| 3 | TSF | 21.5 ha | • Reshape tailings surface to create water shedding profile with simple engineered discharge channel across northern spur.<br>• Drain and cover as per section 10.2.4. Subject to final TSF design, this will require:<br>– 43,030 m³ of material for Zone A sub-base (to be sourced from site borrow pit).<br>– 32,270 m³ of material for liner protection layer (likely to be sourced from site, subject to further soil assessment during detailed design phase, or sourced from offsite at an approximate cost of $40/m³)<br>– 430,270 m³ NAF sourced from the WRD. |
| | WRD | 70.9 ha | • Cover exposed PAF material in encapsulation cells with a 10 m layer of NAF waste rock (will require approximately 316,760 m³ of NAF waste rock sourced from the WRD).<br>• Close as per Section 10.2.3 including reshaping sections to direct surface water away from the pit. |
| | Pit | - | • Complete reshaping TSF and WRD sub-catchments to direct runoff to adjacent catchments.<br>• Manage as per Section 10.2.2. |

| Year | Landform | Approximate Area | Closure Task |
|---|---|---|---|
| 4 | TSF | 24.2 ha | • Reshape tailings surface if required (tailings deposition strategy predicted to form water shedding profile by Year 4).<br>• Drain and cover as per Section 10.2.4. Subject to final TSF design this will require:<br>– 48,410 $m^3$ of material for Zone A sub-base (to be sourced from site borrow pit).<br>– 36,310 $m^3$ of material for liner protection layer (likely to be sourced from site, subject to further soil assessment during detailed design phase, or sourced from offsite at an approximate cost of $40/$m^3$)<br>– 484,110 $m^3$ NAF waste rock sourced from the WRD. |
| | WRD | 79.6 ha | • No exposed PAF material by the end of Year 4<br>• WRD construction will be complete.<br>• Close as per Section 10.2.3 including reshaping sections to direct surface water away from the pit. |
| | Pit | - | • Commence reshaping pit sub-catchments to direct runoff to adjacent catchments.<br>• Manage as per Section 10.2.2. |
| 8+ | TSF | 42 ha | • Reshape tailings surface if required (tailings deposition strategy predicted to form water shedding profile by Year 4).<br>• Drain and cover as per Section 10.2.4. Subject to final TSF design, this will require:<br>– 84,000 $m^3$ of material for Zone A sub-base (to be sourced from site borrow pit).<br>– 63,000 $m^3$ of material for liner protection layer (likely to be sourced from site, subject to further soil assessment during detailed design phase, or sourced from offsite at an approximate cost of $40/$m^3$).<br>– 840,000 $m^3$ NAF waste rock sourced from the WRD. |
| | Pit | - | • Complete reshaping pit sub-catchments to direct runoff to adjacent catchments.<br>• Manage as per Section 10.2.2. |

# 11. CLOSURE MONITORING AND MAINTENANCE

The primary purpose of closure monitoring and maintenance is to assess the success of rehabilitation activities, progress towards achievement of the site completion criteria and timely identification of any need for maintenance work. For the purposes of the Sulphur Springs Project MCP, it is assumed monitoring will be conducted in several phases including:

- Baseline monitoring conducted before operations commence (results that are relevant to closure are summarised in the environment knowledge base).
- Operational monitoring, which occurs throughout the life of the mine (results that are relevant to closure are incorporated in the environment knowledge base and regularly reviewed).
- Pre-closure monitoring, which occurs as the site approaches closure to provide a baseline against which closure performance can be assessed.
- Closure monitoring, which is conducted during the period of active site closure (assumed to be approximately three years following the cessation of operations).
- Post-closure monitoring, which is conducted on an annual basis after final rehabilitation activities reducing as appropriate, until completion criteria targets has been met and the site is able to be relinquished.

Monitoring works will be carried out to assess:

- Compliance with engineering designs and conformance of earthworks to landform and rehabilitation designs.
- Physical stability of rehabilitated areas.
- Chemical stability of tailings and associated groundwater and surface water quality discharges.
- Ecological function of rehabilitated areas.
- Surface water drainage.
- Impacts to groundwater resources.
- Hazards to public safety.
- The requirement for maintenance or remedial work.

Specific components of the monitoring program are described in the following sub-sections.

## 11.1 Monitoring Components and Phases

Closure performance will be monitored during operations (progressive rehabilitation), decommissioning, rehabilitation and post-closure stages of the site until completion criteria have been met and tenure is relinquished.

As part of ongoing closure monitoring, there is a requirement to analyse existing data and determine where gaps exist to demonstrate completion criteria and/or the need for remedial works or ongoing monitoring. The following sub-sections describe a proposed monitoring program that is likely to be applied to the Sulphur Springs site.

Closure and rehabilitation phases and monitoring components are summarised in Table 29. Specific outcomes are defined for each phase of monitoring.

### 11.1.1 Rehabilitation Earthworks Monitoring

Supervision of all earthworks associated with rehabilitation is integral to ensuring final landforms achieve their intended design criteria. Earthworks will be supervised by a suitably qualified specialist who will ensure specifications as detailed in rehabilitation procedures are met. An audit will be undertaken following completion of rehabilitation earthworks to ensure compliance with landform designs. This will be managed under the framework of a detailed Closure Implementation Plan, which will include contractor management procedures.

A quality assurance/quality control program will be developed and implemented during the construction and operational phases to minimise the likelihood of construction and operational errors, especially in relation to progressive rehabilitation.

#### 11.1.2 Post-Closure Monitoring

The purpose of post-closure performance monitoring is to demonstrate achievement of the Sulphur Springs Project completion criteria targets, leading to tenement relinquishment. Post-closure monitoring frequency and duration will be specified closer to mine closure. Major monitoring programs to be conducted during this phase will include:

- Geotechnical assessment for mine waste landforms, TSF embankments and pit walls (if required).
- Identify safety issues and ensure all warning signs and safety barriers are intact.
- Undertake general observations of the presence of erosion and landform stability issues.
- Surface and groundwater monitoring.
- Additional monitoring of pit void, underground workings and surface water management measures as/if required.
- Rehabilitation performance monitoring including vegetation structure, cover and density.
- Monitor soil erosion and control structures.
- Assess the presence of weeds and other pest species and determine control programs.
- General site inspections.
- Identify any maintenance requirements such as remedial earthworks and the removal of sediments from drainage or diversion channels.
- Ensure all infrastructure has been removed and/or appropriately disposed.

Table 29: Closure Monitoring Phases

| Timing | Monitoring Component | Outcome |
|---|---|---|
| Decommissioning | • Rainfall.<br>• Groundwater quality and levels.<br>• Surface water quality and flows.<br>• TSF stability and rehabilitation monitoring including photographic monitoring.<br>• Rehabilitation assessment of other areas.<br>• Visual inspection/soil sampling to identify potential contamination. | • Refine completion criteria.<br>• Re-confirm predictions.<br>• Refine closure designs.<br>• Submit final MCP. |
| During rehabilitation construction earthworks | • Rainfall.<br>• Monitor rehabilitation earthworks.<br>• Audit of compliance with engineering designs.<br>• Groundwater quality and levels including pit lake assessment.<br>• Surface water quality and flows.<br>• TSF stability and rehabilitation monitoring including photographic monitoring.<br>• Rehabilitation assessment of other areas.<br>• Geotechnical audit of abandonment bunds to block portal. | • Design criteria achieved.<br>• Submit completion report to DMIRS. |
| Post Closure Monitoring (Phase 1) | • Rainfall.<br>• Groundwater quality and levels including pit lake assessment.<br>• Surface water quality and flows.<br>• TSF stability and rehabilitation monitoring, including photographic monitoring.<br>• Rehabilitation assessment of other areas.<br>• Surface water management infrastructure stability and effectiveness.<br>• Erosion monitoring (other areas). | • Identify remedial work requirements.<br>• Demonstrate completion criteria achieved.<br>• Submit Phase 1 completion report to DMIRS. |
| Confirmation Monitoring (Phase 2) | • Rainfall.<br>• Groundwater quality and levels.<br>• Surface water quality and flows.<br>• TSF stability and rehabilitation monitoring, including photographic monitoring.<br>• Rehabilitation assessment of other areas.<br>• Surface water management infrastructure stability and effectiveness. | • Monitoring reaffirms achievement of completion criteria. |

### 11.1.3 Quality Assurance

All post-closure monitoring will be carried out by competent persons, following documented monitoring procedures. Monitoring data will be checked, reviewed and reported by suitably qualified persons following appropriate QA/QC procedures. Inspections and monitoring rounds will typically include photographs from established points to verify reports and build a photographic record over time.

All water or soil samples taken for post-closure monitoring will be collected, preserved, stored, handled and transported in accordance with relevant Australian standards, and submitted to an appropriately accredited laboratory for analysis. Monitoring data and supporting laboratory certificates will be maintained in a company database.

#### 11.1.4 Monitoring Schedule

An indicative monitoring schedule is outlined in Table 30. Timelines and monitoring frequency provided will be subject to changes based on the outcomes of monitoring over the LOM and during closure. Maintenance will be undertaken as required and as determined by the monitoring program.

The information collected as part of monitoring activities will be used to assess the progress of the rehabilitated areas towards completion criteria. The results of monitoring activities will be described in the annual environmental report (AER) submitted to DMIRS. Where the data suggests that a criterion may not be achieved, corrective action will be considered in consultation with DMIRS.

**Table 30: Closure Monitoring Schedule**

| Closure Phase | Item | Indicative Frequency |
|---|---|---|
| Decommissioning | Groundwater quality and levels | Quarterly |
| | Surface water quality and flows | Quarterly |
| | TSF stability and rehabilitation | Quarterly |
| | Rehabilitation assessment of other areas | Annually |
| | Visual inspection to identify potentially contaminated soils | Six-monthly |
| Rehabilitation / Earthworks | Visually monitor rehabilitation earthworks | During rehabilitation |
| | Audit of compliance with engineering designs | At completion of earthworks |
| | Groundwater quality and levels | Quarterly |
| | Surface water quality and flows | Quarterly |
| | TSF stability and rehabilitation monitoring | Annual |
| | Rehabilitation assessment of other areas | Annual |
| | Geotechnical Audit of abandonment bunds, TSF | At completion of works, following seasonal rainfall |
| Closure Monitoring (Phase 1) | Groundwater quality and levels including pit lake assessment | Six monthly |
| | Surface water quality and flows | Six monthly |
| | TSF stability and rehabilitation monitoring, including photographic monitoring | Six monthly |
| | Rehabilitation assessment (other areas) | Annual |
| | Surface water management infrastructure stability and effectiveness | Six monthly |
| | Erosion monitoring (other areas) | Annual |
| Confirmation Monitoring (Phase 2) | Groundwater quality and levels | Annual |
| | Surface water quality and flows | Annual |
| | TSF stability and rehabilitation monitoring, including photographic monitoring | Annual |
| | Rehabilitation assessment of other areas. | Annual |
| | Surface water management infrastructure stability and effectiveness | Annual |

### 11.2 Maintenance

Maintenance of the rehabilitated landforms and drainage measures is expected to be necessary during the post-closure period until closure criteria or objectives have been met and relinquishment or handover can be completed. The intention is to leave Venturex and the State Government with no unacceptable liability.

Maintenance activities will be detailed in the final Decommissioning Plan. Broadly, this would involve maintenance of infrastructure required during closure activities and post-closure monitoring programs. Additional maintenance programs, for a period of approximately five years post-completion of rehabilitation, may also include:

- Small-scale landform remediation.
- Repair of any eroded area.
- Repair to surface water management infrastructure.
- Maintenance of containment bunds.
- Road maintenance.
- Weed and pest control.

### 11.3 Reporting

Venturex will report monitoring and remedial or maintenance works associated with implementation of the MCP to DMIRS in the AER for the Project tenements and according to DMP (2015) guidelines, until the Project tenements are relinquished. Any post-closure reporting obligations to the EPA under the Ministerial Statement will also be addressed. Disturbed areas will be reported in annual MRF and AER submissions, until signed off by DMIRS as meeting completion criteria.

Venturex will fulfil reporting obligations that may persist under Part V of the *EP Act* during the post-closure phase. Similarly, any obligations under the *RIWI Act* associated with Licences to Take Water will also be met. Any outstanding contaminated sites investigations and remediation efforts will be reported to DWER.

### 11.4 Finance and Support

Appropriate consideration for monitoring will be included in the closure provision as discussed in Section 12, allowing for a post-closure acceptance period of at least 10 years, and including all labour, equipment, travel consultancy, laboratory and reporting costs. Appropriate risk provision will be made for maintenance contingencies; including mobilisation, accommodation, management, and other support costs for equipment and people should substantial remedial works be required.

As the site is remote, maintenance or remedial actions such as earthworks requiring substantial mobilisation of resources will generally not be carried out piecemeal as and when the need is identified, but as part of a scheduled campaign of work, unless considered urgent. If a substantial campaign of works is required, temporary facilities such as fuel storage, ablutions and an office may be established at the site.

# 12. FINANCIAL PROVISION FOR CLOSURE

## 12.1 Principles

As part of its financial risk management, Venturex intends to maintain sufficient liquidity to meet its obligations as they fall due, under normal and stressed conditions.

Venturex will regularly review its closure liability, which will be progressively informed by actual site experience with the costs and effectiveness of rehabilitation undertaken during the operations phase.

Once the Project commences, Venturex will maintain financial provisions (liabilities of uncertain timing or amount) sufficient to cover incurred closure obligations, in a manner consistent with Australian Accounting Standards Board (AASB) Standard 137 *Provisions, Contingent Liabilities and Contingent Assets*. The closure provisions will be shown on the Venturex financial statement, disclosed as a requirement of its public listing.
Such provisions will address all probable closure obligations arising from the development and operation of the Project to date, including:

- Decommissioning and removal of built infrastructure.
- Investigation and, where necessary, remediation of contaminated sites.
- Rehabilitation earthworks, including encapsulation of adverse materials and restoration of natural drainage.
- Mobilisation, accommodation and maintenance of decommissioning and rehabilitation crews and equipment.
- Closure studies and stakeholder consultation.
- Seed collection and distribution.
- Alteration or servicing of infrastructure, if required as part of any agreement for handover.
- Post-closure monitoring and reporting.
- Project management, consultancy and legal fees.

In addition, the provisions will incorporate appropriate risk adjustment (risk provision or contingency) for:

- Uncertainty in closure obligations, criteria, designs and methods.
- Care and maintenance, and unplanned closure.
- Potential delays or setbacks to decommissioning and rehabilitation works, due to unpredictable events.
- Post-closure maintenance or repairs.

Financial statements will disclose the nature of the closure obligations provided for, the expected timing of expenditure (for the most part, at or shortly after the end of the LOM), and any significant uncertainties or assumptions in the cost estimates. Provisions will be set in “today’s” dollars, based on current estimated closure costs.

Any expected gains on disposal of assets at closure will be recognised separately in accordance with AASB standards and will not be used to offset closure provisions. No gains from the sale of assets, salvage, or scrap at closure will be assumed, until a binding agreement for sale has been reached. Venturex will not assume that any infrastructure can be left in place, until a binding agreement for transfer of liability has been reached, and necessary approvals obtained.

Venturex will account for MRF contributions as an annual operating expense, separate to the closure provision, and contributions will not be used to offset the provision. Accrued redundancy, leave and termination liabilities, that may become payable for a variety of reasons including mine closure or suspension, will be recognised separately from closure provisions in the company statements, in accordance with separate AASB standards.

## 12.2 Review

The Venturex Chief Financial Officer will be responsible for commissioning an annual review of current closure obligations and cost estimates for provisioning on the company financial statements. As part of this, the closure task register (Section 10.2) will be reviewed and updated to consider any changes to:

- The site, including any increase in disturbance, accumulation of mine wastes, new infrastructure, or new (suspected or actual) contaminated sites.
- Closure obligations and criteria arising from studies and consultation that may affect the decommissioning and rehabilitation works required.

The review of the task register will also consider any closure obligations completed to date, including:

- Growth medium and vegetation utilised for progressive rehabilitation activities.
- PAF waste rock material already covered by competent, fresh waste rock.
- Quantity of seed collected.
- Studies completed.
- Detailed designs prepared for closure infrastructure.
- Contamination remediated.
- Progressive rehabilitation earthworks completed.
- Agreements reached for transfer of infrastructure and associated closure liabilities.

Venturex will also determine whether, since the last MCP review, there have been any substantial changes to:

- Applicable rates for any of the closure tasks, and if necessary, recalculate the cost of the affected tasks.
- Uncertainty in closure obligations, criteria, designs or methods, and if necessary, adjust risk provisions correspondingly.

The total cost of outstanding closure tasks and risk adjustments on the register will be used to set the current closure provision. The movement in provision for each reporting period, and any expenditures set against the provision for closure tasks, will be given in financial statements. Only expenditures for closure tasks included in the closure provision will be set against it; the provision will not be used for expenditures unrelated to closure obligations. The provision and underlying cost estimates will be subject to annual external assurance as part of public listing requirements.

Venturex will periodically review the expected timing of closure obligations as part of cashflow forecasting; obligations that will be incurred by planned future development of the Project will also be considered in forecasting, although most of the footprint will be developed, and most closure obligations incurred, early in the Project life.

## 12.3 Cost Estimation Methods

The closure task register will become progressively more detailed over the life of the operations, to allow more detailed and accurate closure cost estimates to be developed. Preliminary estimates for aggregate rehabilitation earthworks on disturbed areas and waste landforms may initially be based (like MRF RLE estimates) on typical aggregate dollar cost per hectare rates for similar works, where such rates can be supported by adequate, recent data from other sites or quotes from earthworks contractors.

As closure planning progresses, closure tasks will be broken down into sub-tasks that can be costed individually. Costs for earthwork tasks that are primarily a factor of area (such as grading and ripping) may be estimated from typical flat dollars-per-hectare rates. Costs that are primarily a factor of volume, such as loading, hauling, and dumping rock and growth medium, may be estimated from typical flat dollars-per-cubic-metre rates.

As planning progresses further, earthworks cost estimates can be refined with estimates that consider:

- Selection of the optimum fleet and labour force for the work, which may incorporate elements of the existing mining fleet to minimise mobilisation costs.
- Development of an optimum schedule for the work, including load-haul-dump movements.
- Site-specific material and landform properties such as densities, gradients and slope lengths, affecting production rates, such as grading and bulk dozer pushing.
- Separate mobilisation, hire, maintenance, fuel, labour, accommodation, management and other cost factors for the selected fleet and labour force.

Venturex will collect data (time taken, resources used, and expenses incurred) on earthworks completed over the life of the operations, including any progressive rehabilitation, to verify and refine rehabilitation estimates. In line with IFRS, estimates will generally assume that all closure works will be done by a third party at current local rates for labour and equipment hire, and not assume that any work will be done in-house.

As the site approaches closure, Venturex may engage specialist decommissioning and mining / earthworks engineers to assist with refining final closure cost estimates. While a relatively small part of total closure costs, Venturex will also seek advice from relevant practitioners on costs for closure studies, contaminated site investigation, and post-closure monitoring and reporting.

# 13. MANAGEMENT OF INFORMATION AND DATA

Venturex will maintain, within a suitable document management system, a library of documents relevant to the closure of the Sulphur Springs Project, including:

- This MCP and revisions.
- Technical reports from baseline and closure studies, including materials characterisations.
- Annual environmental and monitoring reports to regulators.
- Correspondence, minutes of meetings, and other records of engagement and consultation with regulators and other stakeholders.
- Decommissioning and closure works cost estimates, and (when developed) schedules.
- Site plans and landform designs.
- LOM schedules and current mine plans.
- Plans of electrical, water, gas, and other buried services.
- Contaminated sites investigations and reports, if any.
- Journal papers, conference proceedings and other publications with relevant lessons learned at other sites.

Venturex will also maintain, within suitable information management systems, datasets relevant to the closure of the Sulphur Springs Project, including:

- Aerial photographs.
- Areas of disturbance.
- Inventories of rehabilitation materials available and required.
- Records of significant spills, and details of clean-up.
- Data from baseline studies, operations monitoring, closure studies, contaminated sites investigations, and post-closure monitoring, including laboratory certificates where relevant.
- Photographs from pre and post-closure inspections and monitoring rounds.

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# Appendices

# Appendix 1: Stakeholder Engagement Register

**Table A1.1: Stakeholder Register**

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| Atlas Iron Limited (Atlas) | 21/12/2015 | Proposed Sulphur Springs project and regional environmental issues including targeted surveys for *Pityrodia* sp. Marble Bar. | Flora and Vegetation | Atlas and Venturex agreed to share *Pityrodia* sp. Marble Bar survey data to assist in building a greater understanding of populations in the region. |
| DMP - [redacted] | 30/07/2015 | Possible change from dry stack tailings to a conventional valley filled tailings for the Sulphur Springs project. | | [redacted] indicated that DMP has no objection to the concept of a valley filled tailings facility – closure issues would however need to be adequately addressed. |
| DMP - [redacted] | 18/08/2015 | Discussion of the concept of developing an open pit as part of the Sulphur Springs project optimisation study. | Inland Waters and Terrestrial Environmental Quality | [redacted] indicated that DMP has no objection to the concept of an open pit as long as design and closure were adequately addressed. Venturex to consider aspects such as surface and groundwater management and tailings geochemical characteristics in project design and mine closure. |
| DMP - [redacted] | 28/10/2015 | [redacted] provided an e-mail with background information on the environmental issues regarding the proposed TSF that were discussed in 2007/08 as part of the CBH proposal. The e-mail contained correspondence between DMP and EPA as part of the CBH PER assessment. | Inland Waters and Terrestrial Environmental Quality | Venturex to consider aspects such as surface and groundwater management and tailings geochemical characteristics in project design and mine closure. |
| Fortescue Metals Group | 17/12/2015 | Met to discuss proposed Sulphur Springs project and regional environmental issues including targeted surveys for *Pityrodia* sp. Marble Bar. | Flora and Vegetation | FMG and Venturex agreed to share *Pityrodia* sp. Marble Bar survey data to assist in building a greater understanding of populations in the region. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| Department of Parks and Wildlife | 21/03/2016 | Project presentation and discussion of environmental aspects, in particular *Pityrodia*, Leaf- Nosed Bat and Northern Quoll. Potential for two species of Pityrodia rather than one identified. Condition of FMG approval for North Star that they conduct a definitive survey. | Flora and Vegetation, Terrestrial Fauna | There should be no need for Venturex to do an additional *Pityrodia* sp. Marble Bar surveys, given regional survey conditions for FMG. |
| Nyamal People [redacted] | 14/09/2016 | Introductory meeting with [redacted] to discuss the Nyamal people's current group representation since YMAC was dismissed. Also, to identify the appropriate Nyamal people for Venturex to be liaising with regarding activities at Sulphur Springs. | Social Surroundings | [redacted] suggested a meeting with the Nyamal Trust would be a good starting point and offered assistance to arrange a meeting. |
| Indigenous Services - [redacted] | 5/10/2016 | [redacted] provided a clear overview of history between Nyamal and YMAC and their involvement with other Pilbara mining operations. Indigenous services provide a range of roles to mining companies negotiating native title agreements, main contact between companies and indigenous communities and are currently assisting the Nyamal Trust develop their commercial services arm. | Social Surroundings | Venturex would like to meet with [redacted] to further discuss their involvement with the Nyamal people. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| Indigenous Services - [redacted] | 13/10/2016 | Indigenous services has replaced YMAC as the body representing the Nyamal People. They indicated that a law firm McCullogh Robinson from QLD has been appointed as the groups legal representative for Native Title Claims and legal firm Castledine Gregory (from Perth) has been appointed legal representatives for Future Acts. Nyamal group are building a commercial capacity but require partnerships to progress further. | Social Surroundings | Indigenous Services indicated that they represent the Nyamal people and should be the main point of contact for correspondence. |
| Nyamal Peopl [redacted] | 14/10/2016 | Venturex were informed by Native Title division of DMP that [redacted] from Mccullough Solicitors would be representing Nyamal people with respect to MLA45/1253&1245 mediation. An email was sent suggesting we organise teleconference to discuss and resolve matter. | Social Surroundings | An email was sent suggesting Venturex organise a teleconference to discuss and resolve matter. |
| Department of Parks and Wildlife - [redacted] | 24/11/2016 | A phone call to discuss the Sulphur Springs referral and Norther Quoll matters. [redacted] indicated that the Quoll is not a new matter to the Pilbara and can be managed through implementation of appropriate management plans. | Terrestrial Fauna | [redacted] indicated that a meeting was required to address the matter. Venturex offered to send her a copy of the presentation provided to EPA for her records. |
| Indigenous Services - [redacted] | 24/11/2016 | A phone call to discuss arranging a meeting (as representatives of the Nyamal claimants) with Casteldine Gregory (Nyamal future acts representatives) regarding mining tenements and Native Title Tribunal mediation. | Social Surroundings | Venturex to send [redacted] a copy of the Mining agreement which addresses future acts. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| Indigenous Services - [redacted] | 28/11/2016 | [redacted] informed Venturex that he had spoken to [redacted] and [redacted] at Castledine Gregory. They believe there has been no formal objection and it is just following due process as the tenement granting process has been on hold for 12-18 months. He believes the current agreement covers future tenure and no objection should be possible. | Social Surroundings | Indigenous Services reviewed the existing mining agreement and are confident that it adequately addresses existing and future tenements associated with eh Sulphur Springs Project area. |
| Nyamal People - [redacted] | 29/11/2016 | An email request to discuss matters concerning the Nyamal people with [redacted] Aird of Indigenous Services. | Social Surroundings | A copy of the mining agreement and recent correspondence with Indigenous services was provided to [redacted]. |
| Nyamal People - [redacted] | 29/11/2016 | Venturex emailed [redacted] asking who he was accepting instructions from. | Social Surroundings | [redacted] informed Venturex that he took instructions from registered Nyamal Applicants and was acting in accordance with their request. |
| Native Title Tribunal - [redacted] | 1/12/2016 | Phone call to inform Venturex that mediation was postponed at the request of representatives of Nyamal claimants. | Social Surroundings | [redacted] to inform tribunal who the Nyamal representatives will be and a new date for the mediation will be arranged. |
| Hillside - [redacted] | 19/01/2017 | Email and mail correspondence to inform [redacted] of Venturex intention to repair access track. | Social Surroundings | Pastoralists had no concerns with the proposed track upgrade works. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| EPA - [redacted] (EPA Chairman), [redacted] | 19/01/2017 | Venturex met with the EPA chairman to discuss the Sulphur Springs project and present additional information on mine closure matters. DMIRS has raised concerns to the EPA regarding mine closure. If Venturex can develop confidence in DMIRS that they can manage closure, then it is unlikely that the EPA will formally assess the project. However, if mine closure matters cannot be addressed at this stage, then likely to push project through formal assessment. Venturex advised a meeting with DMIRS had already been arranged to discuss closure matters. | All Factors | Venturex to continue to liaise with DMIRS regarding mine closure matters relating to the Sulphur Springs project. |
| DMIRS - [redacted] | 25/01/2017 | Venturex met with DMIRS to discuss mine closure matters for Sulphur Springs project. DMIRS indicated that they did not have sufficient information to determine whether the project could be closed without significant environmental harm (TSF seepage and cover primary concerns). DMIRS was concerned with the additional risks associated with the current TSF when compared to the approved TSF (dry stacked tails). | Inland Waters and Terrestrial Environmental Quality | Venturex to further develop mine closure concepts. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| DMIRS - [redacted] | 1/02/2017 | Venturex contacted [redacted] at DMIRS to discuss information requirements on mine closure matters that would provide DMIRS with confidence that closure can be managed through the DMIRS processes. [redacted] asked for a copy of the letter from EPA so they can respond appropriately. Venturex provided a copy of the letter to him and awaiting feedback. | Inland Waters and Terrestrial Environmental Quality | Venturex to provide copy of EPA letter to DMIRS to enable for further discussion of the matters raised. |
| DMIRS - [redacted] | 13/02/2017 | Followed up with [redacted] on his meeting with EPA and whether he can now advise on the type and level of information DMIRS requires to assist with the approvals pathway determination process. | Inland Waters and Terrestrial Environmental Quality | Venturex offered to arrange a meeting to progress further given tight timeframe for Venturex to respond to the EPA. |
| DMIRS, DWER | 20/02/2017 | Venturex provided further information and discussed TSF design and closure concepts with government agencies to assist with making a decision on the approvals pathway for the Sulphur Springs Project. | Inland Waters and Terrestrial Environmental Quality | Electronic copy of the presentation and meeting minutes are to be provided to all in attendance at the meeting. No new issues were raised at the meeting that had not previously been discussed with the government agencies. |
| DMIRS [redacted] | 23/02/2017 | Meeting with DMIRS to follow up from discussions held at meeting on 20th February and discuss response to EPA. | Inland Waters and Terrestrial Environmental Quality | Venturex will investigate an alternative TSF location within the open pit water catchment to address DMIRS concern regarding seepage. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| DMIRS - [redacted] (Geotechnical Engineer) | 10/03/2017 | Discussed an alternative TSF location on the WRD at Sulphur Springs. [redacted]) developed some concept plans which show all tailings can be stored within the WRD footprint. DMIRS geotechnical engineers appeared comfortable with the concept despite it being located closer to open pit/underground workings than any other approved operation. | Inland Waters and Terrestrial Environmental Quality | The concept would be further developed by [redacted] in the following weeks and a meeting between [redacted] and DMIRS geotechs would be arranged to discuss design criteria. |
| Town of Port Hedland - [redacted] (Manager Infrastructure and Projects) | 22/03/2017 | Met with [redacted] to provide an overview of Venturex and the Sulphur Springs project. The Shire supports development and diversification of commodities in the region and was interested to hear about the project. | Social Surroundings | The Shire offered Venturex any support required to assist with the project. |
| Pilbara Development Commission - [redacted] (Director People, Place and Community) | 22/03/2017 | Met with [redacted] to provide an overview of Venturex and the Sulphur Springs project. The Commission supports development and diversification of commodities in the region and was interested to hear about the project. Offered Venturex any support required to assist with the project. She is interested in any community development programs and indicated that the Commission can provide financial support for such programs if required. | Social Surroundings | The Development commission offered any support required to assist with the projects development. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| Nyamal People - [redacted] and the Nyamal People Applicant Group | 22/03/2017 | A meeting of the Nyamal Applicant group was being held in Port Hedland organised by [redacted] from Indigenous Services. Venturex provided an update of the Sulphur Springs project at the meeting. There were 8 representatives from Nyamal at the meeting including [redacted] (with his mother and sister), [redacted] (an initiated Elder) and three additional Nyamal representatives. Key issues discussed were contracts, employment and cultural heritage training included in the sites induction process. [redacted] also mentioned that protection of the indigenous etchings close to the main access track was very important. | Social Surroundings | Further discussions regarding content and delivery of a cultural awareness training session to Venturex will be arranged with [redacted] |
| DMIRS - [redacted] | 6/04/2017 | Venturex e-mailed [redacted] a copy of the draft closure criteria developed by O'Kane for inclusion into the closure concept cover design report for his review and comment to ensure all DMIRS requirements are addressed in the closure cover design. | Inland Waters and Terrestrial Environmental Quality | DMIRS will review the draft closure criteria and will provide comments to Venturex. |
| DMIRS, DWER and project consultants | 26/04/2017 | MBS Environmental facilitated a TSF options evaluation workshop. A risk assessment matrix and summary of the two TSF design options was provided to all attendees and an options analysis template was developed prior to the workshop. The template was populated during the workshop for inherent consequence for a range of potential unwanted events. | Inland Waters and Terrestrial Environmental Quality | The outcomes of the assessment indicated that the integrated waste landform option had greater risks associated with engineering and construction, safety during operation and potentially may sterilise a resource. For these reasons this option was no longer considered viable. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| DMIRS [redacted] | 4/05/2017 | Met with DMIRS to confirm outcomes of the TSF options assessment from meeting held on 26th April and briefly discussed Venturex's planned response to the EPA. | Inland Waters and Terrestrial Environmental Quality | DMIRS will provide formal comments to EPA. |
| Nyamal People [redacted] | 7/06/2017 | Venturex explained proposed exploration program and earthworks to improve track. Conducted site visit to the proposed drill locations and [redacted] indicated location of the heritage site along access track. [redacted] indicated she had not been back to this country in decades. There is some bush tucker onsite including bush tomatoes and rockmelon which [redacted] pointed out but no food collection currently occurs on these lands by Nyamal. | Social Surroundings | No concerns with proposed exploration activities were raised by the Nyamal representatives during the site visit and exploration activities will proceed as planned. |
| Atlas Iron [redacted] | 26/07/2017 | Met to discuss timeframe for Abydos closure and infrastructure requirements. Atlas indicated that production will cease in late October with haulage ceasing during November. Camp will be operational until November but after that they are unsure. Camp will most likely be moved to their Corunna Downs operation - however that is timing dependant. They are likely to remove the Telstra tower soon after November. They will require access to the camp for ongoing monitoring and closure activities but will not be racing to complete rehab requirements. | | Venturex expressed interest in the Abydos camp and further discussions regarding this asset are proposed with Atlas. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| Nyamal People [redacted] | 26/10/2017 | [redacted] called up that morning to ask if he, his mum [redacted] and [redacted] could drop in to say G'day. They talked about the cultural awareness training session they have conducted recently with Pilbara Minerals and are keen to run Venturex personnel through the same course. They invited Venturex to attend the Native title determination ceremony proposed in April. We discussed the MALC meeting dates and he tentatively confirmed 22nd Nov works for them. I suggested he pass that back through [redacted] so we can book the venue/participants and develop an agenda. Introduced them to the Venturex team and to [redacted] who was also in the office. | Social Surroundings | Venturex and Nyamal to confirm MALC meeting dates and identify potential dates for the cultural awareness training session. |
| Nyamal People [redacted] | 29/11/2017 | MALC meeting held with indigenous groups in Nyamal office South Perth. Venturex provided project update presentation and discussion on changes to the current mining agreement. Nyamal provided details on cultural awareness training sessions and asked if they could present one to Venturex early in 2018. Minutes from the meeting have been developed and issued to all the attendees. | Social Surroundings | Formal engagement with Nyamal representatives has been re-established. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| DMIRS - [redacted] | 7/12/2017 | Met with DMIRS to discuss environmental approvals progress. Provided details of additional surveys that have been undertaken and the results obtained to date from those surveys. Also discussed the MCP and requirement for DMIRS to agree in principal to the preliminary MCP prior to submission of the ERD to the EPA. | Inland Waters and Terrestrial Environmental Quality | No additional concerns were raised by DMIRS on the survey work undertaken for the project or on mine closure matters. |
| Nyamal People - [redacted] | 3/05/2018 | Engaged [redacted] to deliver a cultural awareness training session to senior personnel at Venturex. The session included discussions relating to - Culture, Identity and Aboriginality, - Country, Heritage and spirituality - History of Nyamal People - Working with Nyamal people Also discussed current connection with the project area - [redacted] indicated that the Nyamal people moved off the land many centuries ago with the majority residing in Port Hedland, Broome and Perth. Ceremonies are still performed on sacred ground along the Shaw River but no gathering of food from the land occurs within the Sulphur Springs area. | Social Surroundings | Cultural awareness training session was well received by all and further training sessions for additional Venturex staff will be considered. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| DMIRS - [redacted] | 10/05/2018 | Met with [redacted] to provide an update on the projects progress and key findings of the studies completed for the project. Also discussed mine closure aspects particularly associated with the TSF, WRD and pit water diversion. I suggested that we meet again once the ERD has been submitted to the EPA to go through any queries regarding the MCP prior to DMIRS providing their comments to the EPA. | Inland Waters and Terrestrial Environmental Quality | Meeting to be arranged with DMIRS following submission of the ERD to the EPA. |
| EPA - [redacted]<br>DMIRS - [redacted] | 27/07/2018 | Site visit to Sulphur Springs by EPA and DMIRS representatives to support the project assessment process. All key environmental factors were discussed and all infrastructure footprints visited during the site visit. | All Factors | Site visit was well received by all and put topographic constraints into perspective. |
| DMIRS [redacted] | 5/09/2018 | Met with DMIRS to discuss their comments on the ERD to EPA re mine closure. Wanted to understand DMIRS concerns to ensure Venturex response adequately address DMIRS concerns. | Inland Waters and Terrestrial Environmental Quality | Two key issues identified as requiring further information relating to potential seepage from the TSF and pit lake water management post closure. Venturex to provide additional information on these aspects to DMIRS. |
| DoEE - [redacted] | 19/09/2018 | Contacted DoEE following request from EPA. Discussed why project was not referred to the DoEE under the EPBC Act. Also discussed the previous underground only mining option which was referred to the DoEE for project certainty. | Fauna and Flora | [redacted] wanted to discuss further with colleagues and will call back in a few days. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| DoEE - [redacted] | 20/09/2018 | DoEE sought clarification that the previous decision not to assess the sulphur springs project (underground only mining option) was not being used for current project footprint. The previous project (underground only) was referred purely for project surety and not for significant impacts to any MNES. Self-assessment was conducted for current project footprint against EPBC Act criteria and no significant impacts to MNES identified. Decision not to refer was determined. | Fauna and Flora | DoEE indicated that they were comfortable with the approach taken and that due process and consideration of required guidelines had been followed. DoEE did not require any further detail regarding the project. |
| EPA - [redacted] | 20/09/2018 | Followed up with EPA on clarification of comments received to enable comments to be appropriately and adequately addressed by Venturex. EPA was unable to provide any further clarification on the matters raised and suggested Venturex provide response to their own interpretation of the EPA comments. | All Factors | |
| DMIRS - [redacted] | 24/10/2018 | Met with DMIRS to provide feedback from additional information gathered in response to two queries raised on the ERD associated with potential TSF seepage and pit water diversion post closure. | Inland Waters and Terrestrial Environmental Quality | Meeting with Resource Safety Department at DMIRS to be arranged to discuss design criteria for proposed mine closure infrastructure. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| DMIRS - [redacted] | 30/10/2018 | Met with DMIRS Resource Safety to discuss pit diversion dam wall and proposed tunnel at closure. [redacted] indicated that a tunnel would likely remain insitu for a longer time period than a dam wall and had no concerns in principle regarding the construction of a tunnel post closure for permanent water diversion. | Inland Waters and Terrestrial Environmental Quality | No further action required. |
| EPA - [redacted] (EPA Chairman), [redacted] | 6/02/2019 | Met with EPA Chairman to discuss approvals process and the impasse Venturex finds itself with DMIRS on mine closure matters and seeking agreement on a way to move forward. An independent third party review may be required on mine closure. The precise aspects/s for the review would need to be confirmed with DMIRS and EPA. [redacted] will follow up with DMIRS and provide details for the review. Venturex will provide the EPA with a detailed response to the additional comments raised by DMIRS in the EPA letter. | Inland Waters and Terrestrial Environmental Quality | EPA to define questions/aspects to be addressed via a peer review. Venturex to commission a consultant to undertake the peer review. |
| Nyamal People - [redacted] | 25/3/2019 | Introduction with [redacted]<br>Discussion around commercial opportunities | | Agreement to continue dialogue |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| Nyamal People - [redacted] | 18/4/2019 | Ongoing discussion around opportunities and tendering process | | |
| EPA, EPAS, DMIRS, DWER | 29/8/2019 | Multi agency meeting to discuss outstanding regulatory issues/concerns including TSF seepage, pit lake water quality, surface water diversion and mine closure risks. Attended by Venturex, specialist consultants including peer reviewers | All | Residual issues to be addressed in revised ERD. ERD V4 submitted 5 September 2019. |
| DWER - Part V and EPAS | 2/9/2019 | Site Water balance, water management, treatment and TSF design | | Email response sent post meeting. |
| EPAS | 2/9/2019 | Discussion to confirm focus remains on addressing Part IV assessment issues at this stage | | |
| EPAS | 10/9/2019 | Status check – approvals process<br>Potential solutions to closure concerns<br>Assessment options; S43a vs S45c | Inland Waters and Terrestrial Environmental Quality | |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| EPAS | 17/9/2019 | Discussion on ERD and appendices V4 points of clarification and inconsistencies. | | |
| DMIRS - [redacted] | 30/10/2019 | Key unresolved risks<br>Tailings Storage Facility - seepage during operations and post closure; long term stability and management post closure (quantum, administration of bond).<br>Pit Overflow – uncertainty over catchment diversion dam and tunnels enduring in perpetuity.<br>Opening discussion on potential to relocate TSF to address closure risks<br>Further discussions to occur, including with DMIRS Geotech (safety) | Inland Waters and Terrestrial Environmental Quality | While DMIRS has indicated it is technically possible to regulate/manage closure risks under the Mining Act, considerable complexity and uncertainty remains. As a consequence, alternative TSF location is being investigated by Venturex |
| Nyamal People - [redacted] ALMA Legal | 4/11/2019 | Monitoring and Liaison Committee Meeting<br>Project update, development/commercial opportunities<br>Nyamal support for project reiterated. | | Dialogue maintained |
| EPAS | 6/11/2019 | Engagement update. Potential proposal change to resolve perceived outstanding closure risks. S43a criteria, process and timing. | Inland Waters and Terrestrial Environmental Quality | Subject to outcomes of current investigations, Venturex to prepare and submit request to amend proposal under Section 43a. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| DMIRS -Environment and Geotech | 11/11/2019 | Proposal and assessment background/history. Geotechnical/safety considerations of locating tailings upgradient of mine pit. Preliminary risk reduction measures | Inland Waters and Terrestrial Environmental Quality | No fatal flaws identified in proposed TSF relocation. Investigations and preparation of S43a request to proceed. |
| EPAS and DWER Regulatory Services | 18/11/2019 | Briefing on proposed changes to proposal to resolve closure risks. Brief discussion on tailings management, Part V implications and Part V approval timing. | Inland Waters and Terrestrial Environmental Quality | No fatal flaws expressed in proposed changes. Investigations and preparation of S43a request to continue. |
| EPAS | 2/12/2019 | Change to proposal – required revisions to ERD<br>EPA meeting Feb 2020 and ERD V6 consideration | Inland Waters and Terrestrial Environmental Quality | Relocation of TSF and water related studies maintained. ERD V6 to be submitted late January for February 2020 EPA consideration. |
| DMIRS | 10/12/2019 | Project update TSF relocation studies/safety mgt. ERD V6 timing (late January 2020).<br>Reconciliation of existing approved and future Mining Proposals | Inland Waters and Terrestrial Environmental Quality | Relocation of TSF and water related studies maintained. ERD revision (V6) to continue. |
| DWER Regulatory Services | 19/12/2019 | Project update, rationale behind proposal changes. Detail of relocated TSF – no HDPE base liner, water/tails mgt. Pt V information requirements and indicative works approval application timing.<br>ERD V6 timing late January 2020 for EPA Feb 2020 meeting. Staged Works Approvals applications could be submitted in March and May-June after further detailed design. | Inland Waters and Terrestrial Environmental Quality | Relocation of TSF and water related studies maintained. ERD revision (V6) to continue. More detail to be provided on appropriate water treatment of tailings decant water. |

| Stakeholder | Date | Issues/topics raised | Environmental Factor/s | Proponent Response / Outcome |
|---|---|---|---|---|
| Director of Property and Risk Management<br>Department of Planning, Lands and Heritage | 15/01/2020 | Project overview. Focus on closure and post mining landform. TSF relocation rationale and management of final pit void.<br>DPLH principal interest is in observance of Native Title Act requirements, confirming land tenure is in order and Indigenous Cultural Heritage matters properly addressed. DPLH wants to ensure it is not inheriting an area that requires ongoing management/costs in order to prevent risk/impact to public health and safety and to other stakeholders (pastoralists).<br>DMIRS is the primary regulator and will DMIRS/EPA generally involve DPLH in commenting on proposals. | Inland Waters and Terrestrial Environmental Quality | No further action require of Venturex at this stage. |

# Appendix 2: Sulphur Springs Soil Assessment (Outback Ecology 2013)





# Venturex Resources Limited

# Sulphur Springs Copper Zinc Project

Soil Resource Assessment

April 2013

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# Venturex Resources Limited

# Sulphur Springs Copper Zinc Project - Soil Resource Assessment

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| RMDSTEM Limited (on behalf of Venturex Resources Limited) | 1 x electronic | A. Robertson |

**Document Control for Job Number: SULP-SS-12001**

| Document Status | Author | Reviewer | Signature | Date of Issue |
|---|---|---|---|---|
| Draft Report | A. Byrne | M. Braimbridge | MB | 25 Jan 2013 |
| | | A. Robertson (RMDSTEM Limited) | | 29 Jan 2013 |
| Final Draft Report V1.0 | | M. Braimbridge | MB | 30 Jan 2013 |
| Final Draft Report V2.0 | | M. Braimbridge | MB | 22 Apr 2013 |
| Final Report | | B. Gordon | BG | 24 Apr 2013 |

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## Executive Summary

Outback Ecology was commissioned by Venturex Resources Limited (Venturex) to characterise potential soil materials and develop a soil resource inventory for the proposed Sulphur Springs Copper Zinc Project (the Project). The Project is located in the Pilbara Region of Western Australia, situated approximately 110 kilometres (km) south-east of Port Hedland and 57 km west of Marble Bar.

The aim of the soil characterisation programme was to assess topsoil and subsoil resources from the Project area and surrounding areas, which may be available for use as a rehabilitation medium and / or as a component of the cover for the proposed tailings storage facilities (TSFs). A soil resources inventory has been developed and recommendations for the use of available soil resources, as a source of cover materials for the proposed TSFs, have been outlined.

Soils from within the Project area were sampled by Venturex personnel on three separate occasions, in December 2011, November 2012 and February 2013. A summary of the physical and chemical characteristics of the soils is provided in (**Table ES1**).

*Soil physical characteristics*

The texture of the soil sized fraction (<2 mm) of the soils from the Project area ranged from 'loamy sand' (4.8% clay) to 'sandy clay' (29% clay) (**Table ES1**). The amount of coarse material (>2 mm) present within Project area soils ranged from 11% to 81%. Overall, the Kangaroo Caves, Eastern and Air Strip area soils had comparatively less clay fraction and less coarse material content than the 2011 and 2012 Project area soils.

The degree of clay dispersion in the soils, as measured by the Emerson Aggregate Test, was variable, with Emerson Test Classes of 2, 3a, 3b, 4, 5, 6 and 8 recorded (**Table ES1**). The majority of the soils were considered 'stable' to 'moderately stable', from a clay dispersion perspective.

The saturated hydraulic conductivity, and associated drainage classes, for the majority of soils ranged from 'moderate' to 'moderately rapid' (**Table ES1**), indicating a moderate potential for the soil to accept rainfall and, in combination with the high percentage of coarse material (particularly for the 2011 and 2012 Project area soils), a relatively low potential erodibility for these soils. This, however, comes at the cost of a lower water holding capacity for the soils with a high amount of coarse (competent rock) material. In contrast, the Kangaroo Caves, Eastern and Air Strip area soils have a comparatively lower percentage of coarse material and therefore a greater water holding capacity (**Table ES1**), but are comparatively more prone to erosion.

The majority of Kangaroo Caves, Eastern and Air Strip area soils (<2 mm sized fraction) are considered not prone to hardsetting. However, a number of the 2011 and 2012 Project area soil samples were considered prone to hardsetting, with soil strength values exceeding the 60 kPa value, indicative of hardsetting soils (**Table ES1**).

*Soil chemical characteristics*

The relatively low EC values (**Table ES1**) of the majority of the soils sampled, indicate that there is a low risk of salinity related issues occurring if the topsoil and sub surface soils are used as a surface rehabilitation medium. The pH of the soils was variable (pH ($CaCl_2$) 4.5 to 8.3), with soil pH unlikely to be a limiting factor to successful vegetation growth of rehabilitated areas.

The majority of the soils (<2 mm sized fraction) from the Project area are considered non-sodic (**Table ES1**) with the exchangeable sodium concentrations being below the level of detection for the majority of samples. The low exchangeable sodium percentages (ESP) correlates to the low degree of clay dispersion observed for the majority of the soils sampled.

The majority of soils from the Project area had 'low' concentrations of organic carbon and 'low' to 'moderate' levels of plant-available nutrients, typical of the surface soils in the Pilbara region (**Table ES1**).

Analysis of total metals (**Table ES1**) indicates that the total metal concentrations of the soil materials sampled are typically low, with some concentrations of total nickel, copper and zinc above their respective Ecological Investigation Levels (EILs). These values are however, seen as a natural occurrence and pose no risk in terms of the use of the material for rehabilitation purposes.

*Use of soil resources for the TSF cover*

The soil store-release layer of the proposed TSF cover will need to be capable of holding water from the majority of rainfall events and resilient enough to shed water from high intensity rainfall events. The soil store-release component will also need to support the growth of native vegetation which will assist in the release of stored water, as will evaporation from the outer surface. The analyses performed as part of this investigation indicate that, while there is substantial variation in many of the physical and chemical characteristics of the soils present, the majority are likely to be suitable for use as a surface cover / rehabilitation medium.

The 2011 and 2012 Project area soils have a high percentage of coarse rock and a 'moderate' to 'moderately high' drainage capacity, indicating a low inherent erodibility. The water retention characteristics of these soils indicate that, assuming homogenous infiltration and water storage (i.e. no preferential flow), the soils have a USL, on average, of approximately 15% (by volume). This means that a 1.0 m depth of soil will hold approximately 150 mm of rainfall. These characteristics make the 2011 and 2012 Project area soils potentially suitable as component of the outer 'erosion resistant' surface cover.

In contrast, the Kangaroo Caves, Eastern and Air Strip area soils have a lower percentage of coarse rock, indicating they are likely to be more prone to erosion. These soils have a USL, on average, of approximately 23% (by volume). This means that a 1.0 m depth of soil will hold approximately 230 mm of rainfall. These characteristics make the Kangaroo Caves, Eastern and Air Strip area soils potentially suitable as a soil water storage layer situated below the outer 'erosion resistant' cover.

Regional rainfall data indicates that the 1 in 100 year 72 hour rainfall event is 379 mm (BoM 2012). A potential depth of 'rocky' soil for the outer 'erosion resistant' soil layer has been indicated as 1.0 m which, based on a USL of 15%, would hold approximately 150 mm of rainfall. In addition, a potential depth of soil for the water storage layer has been indicated as 3.0 m, which, based on a USL of 23%, would hold approximately 690 mm of rainfall. This assumes homogenous infiltration of rainfall, a negligible amount of existing water storage in the soil materials and no surface run-off. As the TSF cover will be designed to shed any rainfall which falls at a rate greater than the infiltration capacity of the surface soil materials, the water retention ability of the proposed cover depths is considered likely to be adequate to restrict the downward movement of water from rainfall.

Current data, supplied by Venturex personnel, indicates that further volumes of, as yet, unassessed soil materials within the Airstrip area. These soil resources may potentially provide a source of material suitable or the clay sealing component of the TSF cover. This will require further investigation as the Project develops.

*Soil resource inventory*

Based on the current soil resources inventory for areas of disturbance within the Project area, a volume of approximately 3,511,155 $m^3$ of soil has been identified as potentially available for salvage. A soil cover of 3.0 m depth on the final TSF surface at closure would require a volume of soil over 600,000 $m^3$. This indicates a substantial surplus in the currently available soil resources required for the final cover, rehabilitation and closure of the TSFs. This information is based on approximate soil volume calculations derived from spatial and soil depth information supplied by Venturex personnel.

*Recommendations for further investigations*

Recommendations for further investigations to refine the proposed TSF cover design include:

- further identification of a suitable source of clay materials from the Airstrip areas, for the clay sealing layer, and geochemical assessment of the compacted permeability of those materials;
- identification of a suitable source of clean competent rock to enhance the geotechnical stability and surface stability (i.e. surface armour) of the TSF cover if required;
- modelling of water balance of the TSF cover, expected runoff, drainage and sediment loss; and
- a commitment to establishment of field trials of TSF cover components, including evaluation of water storage capacity, erodibility and rehabilitation parameters. A conceptual design of the field trials could be established to demonstrate a commitment to evaluation of TSF cover options.

**Table ES1: Summary of physical and chemical characteristics of soil samples from the Sulphur Springs Copper Zinc Project area. The figures presented represent average values with broad ratings of good, moderate and poor for each parameter relative to suitability for plant growth and/or overall material stability**

| Description | Site | Total soil depth (m) | Approx. area of soil present ($m^2$) | Sample depth (cm) | Physical characteristics | | | | | | Chemical characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Soil texture[1] | Coarse material content (%)[2] | Emerson Class[3] | (Modulus of Rupture (kPa) | Hydraulic conductivity (mm/hr) | Upper storage limit (% vol)[4] | pH ($CaCl_2$) | Salinity class (dS/m) | Organic carbon (%) | Nutrient status | Exchangeable Sodium Percentage (%)[5] | Total metal concentrations[6] |
| Project area soil 2011 | Site A1 | - | - | 0-5 | Sandy loam | 67 | 3b Moderately stable | 52.9 Non-hardsetting | - | - | 5.5 Neutral | 0.021 Non-saline | 0.43 Low | Low to medium | BDL Non-sodic | Low (high Zn) |
| | | | | 10-20 | Clayey sand | 81 | 3b Moderately stable | 72.3 Hardsetting | - | - | 5.4 Slightly acidic | 0.020 Non-saline | 0.18 Low | Low to medium | BDL Non-sodic | - |
| | | | | 40-50 | Clayey sand | 75 | 3b Moderately stable | 111.5 Hardsetting | 52.01 Moderate | - | 5.5 Neutral | 0.026 Non-saline | 0.17 Low | Low to medium | BDL Non-sodic | Low (high Ni, Zn) |
| | Site A2 | - | - | 0-5 | Clayey sand | 63 | 5 Stable | 44.6 Non-hardsetting | - | - | 4.8 Moderately acidic | 0.036 Non-saline | 0.41 Low | Low to medium | BDL Non-sodic | Low |
| | | | | 10-20 | Sandy clay loam | 77 | 6 Stable | 36.6 Non-hardsetting | - | - | 4.6 Moderately acidic | 0.016 Non-saline | 0.12 Low | Low to medium | BDL Non-sodic | - |
| | | | | 40-50 | Clayey sand | 71 | 6 Stable | 33.5 Non-hardsetting | 18.8 Moderately slow | - | 4.5 Moderately acidic | 0.014 Non-saline | 0.12 Low | Low to medium | BDL Non-sodic | Low |
| | Site A3 | - | - | 0-5 | Clayey sand | 70 | 2 Unstable | 68.8 Hardsetting | - | - | 5.9 Neutral | 0.069 Non-saline | 0.18 Low | Low to medium | 8.16* Sodic | Low |
| | | | | 10-20 | Clayey sand | 71 | 2 Unstable | 115.1 Hardsetting | - | - | 6.1 Neutral | 0.046 Non-saline | 0.12 Low | Low to medium | 7.04* Sodic | - |
| | | | | 40-50 | Sandy clay loam | 71 | 2 Unstable | 146.7 Hardsetting | 13.62 Moderately slow | - | 6.1 Neutral | 0.068 Non-saline | 0.15 Low | Low to medium | 14.08* Sodic | Low |
| | Site A4 | - | - | 0-5 | Sandy clay loam | 67 | 2 Unstable | 126.8 Hardsetting | - | - | 7.3 Moderately alkaline | 1.511 Very saline | 0.15 Low | Low to medium (high N, S) | 2.44 Non-sodic | Low |

| Description | Site | Total soil depth (m) | Approx. area of soil present ($m^2$) | Sample depth (cm) | Physical characteristics: Soil texture[1] | Coarse material content (%)[2] | Emerson Class[3] | (Modulus of Rupture (kPa) | Hydraulic conductivity (mm/hr) | Upper storage limit (% vol)[4] | Chemical characteristics: pH ($CaCl_2$) | Salinity class (dS/m) | Organic carbon (%) | Nutrient status | Exchangeable Sodium Percentage (%)[5] | Total metal concentrations[6] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 10-20 | Clay loam | 58 | 6 Stable | 130.2 Hardsetting | - | - | 7.3 Moderately alkaline | 3.415 Extremely saline | 0.23 Low | Low to medium (high N, S) | 3.73 Non-sodic | - |
| | | | | 40-50 | Sandy loam | 43 | 6 Stable | 42.2 Non-hardsetting | 13.93 Moderately slow | - | 7.5 Moderately alkaline | 3.930 Extremely saline | 0.22 Low | Low to medium (high N, S) | 3.50 Non-sodic | Low |
| | Site A5 | - | - | 0-5 | Sandy loam | 65 | 3b Moderately stable | 57.5 Non-hardsetting | 65.77 Moderately rapid | - | 4.6 Moderately acidic | 0.012 Non-saline | 0.51 Low | Low to medium | BDL Non-sodic | Low |
| | | | | 10-20 | Sandy loam | 59 | 5 Stable | 87.2 Hardsetting | - | - | 5.0 Slightly acidic | 0.060 Non-saline | 0.27 Low | Low to medium | BDL Non-sodic | - |
| | Site A6 | - | - | 0-5 | Loam | 49 | 5 Stable | 23.0 Non-hardsetting | 13.95 Moderately slow | - | 5.0 Slightly acidic | 0.015 Non-saline | 0.25 Low | Low to medium | BDL Non-sodic | Low |
| | | | | 10-20 | Sandy clay loam | 69 | 5 Stable | 72.9 Hardsetting | - | - | 5.0 Slightly acidic | 0.028 Non-saline | 0.18 Low | Low to medium | BDL Non-sodic | - |
| Project area soil 2012 | Site 1 | 0.7 | 44,919 | 0-20 | Sandy loam | 60 | 8 Stable | 52.5 Non-hardsetting | 44.71 Moderate | 18.7 | 8.0 Moderately alkaline | 0.098 Non-saline | 0.72 Low | Low (high K) | BDL Non-sodic | Low (high Ni) |
| | | | | 40-60 | Loamy sand | 56 | 4 Stable | 63.7 Hardsetting | 69.58 Moderately rapid | 16.2 | 8.2 Strongly alkaline | 0.101 Non-saline | 0.24 Low | Low | BDL Non-sodic | Low |
| | Site 2 | 0.4 | 52,828 | 0-20 | Sandy clay loam | 76 | 3b Moderately stable | 81.9 Hardsetting | 23.90 Moderate | 6.1 | 5.8 Neutral | 0.034 Slightly saline | 0.45 Low | Low | BDL Non-sodic | Low |
| | Site 3 | 1.0 | 15,013 | 0-20 | Clay loam | 73 | 8 Stable | 194.3 Hardsetting | 86.26 Moderately rapid | 11.2 | 7.4 Moderately alkaline | 0.02 Non-saline | 0.85 Low | Low | 7.38* Sodic | Low |
| | | | | 40-60 | Silty loam | 28 | 2 Unstable | 394.5 Hardsetting | 1.49 Slow | 33.8 | 7.9 Moderately alkaline | 0.064 Non-saline | 0.10 Low | Low (high S) | 24.05* Highly sodic | Low |
| | Site 4 | 0.4 | 16,299 | 0-20 | Sandy clay | 57 | 3a Moderately stable | 76.2 Hardsetting | 42.71 Moderate | 15.0 | 7.1 Moderately alkaline | 0.476 Moderately saline | 0.46 Low | Low (high K) | BDL Non-sodic | Low (high Cu, Ni) |

| Description | Site | Total soil depth (m) | Approx. area of soil present ($m^2$) | Sample depth (cm) | Physical characteristics | | | | | | Chemical characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Soil texture[1] | Coarse material content (%)[2] | Emerson Class[3] | (Modulus of Rupture (kPa)) | Hydraulic conductivity (mm/hr) | Upper storage limit (% vol)[4] | pH ($CaCl_2$) | Salinity class (dS/m) | Organic carbon (%) | Nutrient status | Exchangeable Sodium Percentage (%)[5] | Total metal concentrations[6] |
| | Site 5 | 1.2 | 18,693 | 0-20 | Sandy loam | 34 | 5 Stable | 42.4 Non-hardsetting | 44.10 Moderate | 21.5 | 7.5 Moderately alkaline | 1.764 Very saline | 0.95 Low | Low (high K) | BDL Non-sodic | Low (high Cu, Ni, Zn) |
| | | | | 40-60 | Silty loam | 51 | 4 Stable | 161.1 Hardsetting | 27.28 Moderate | 18.2 | 8.3 Strongly alkaline | 0.027 Slightly saline | 0.20 Low | Low (high K) | BDL Non-sodic | Low (high Cu) |
| | | | | 100-120 | Loamy sand | 68 | 5 Stable | 23.6 Non-hardsetting | 156.21 Rapid | 12.1 | 8.2 Strongly alkaline | 0.069 Non-saline | 0.24 Low | Low | 16.20* Highly sodic | Low (high Cu) |
| | Site 6 | 1.0 | 16,755 | 0-20 | Sandy clay | 74 | 3b Moderately stable | 153.3 Hardsetting | 90.61 Moderately rapid | 11.5 | 6.6 Neutral | 0.042 Non-saline | 0.19 Low | Low (high K) | BDL Non-sodic | Low (high Ni) |
| | | | | 40-60 | Sandy clay | 63 | 3b Moderately stable | 237.3 Hardsetting | 53.14 Moderate | 12.6 | 6.7 Neutral | 0.148 Non-saline | 0.15 Low | Low (high K) | BDL Non-sodic | Low (high Cu, Ni) |
| TSF Area B footprint soil 2012 | Site 7 | 0.05 | 47,144 | 0-5 | Sandy loam | 61 | 3b Moderately stable | 73.7 Hardsetting | 80.43 Moderately rapid | 14.8 | 6.9 Neutral | 0.018 Non-saline | 0.78 Low | Low (high K) | BDL Non-sodic | Low |
| | Site 8 | | | 0-5 | Sandy loam | 80 | 3a Moderately stable | 153.8 Hardsetting | 10.39 Moderately slow | 8.0 | 5.6 Neutral | 0.121 Non-saline | 0.92 Low | Low (high K) | BDL Non-sodic | Low |
| TSF Area A footprint soil 2012 | Site 9 | 0.05 | 159,055 | 0-5 | Sandy clay loam | 71 | 2 Unstable | 135.7 Hardsetting | 15.90 Moderately slow | 13.0 | 6.1 Neutral | 0.033 Non-saline | 0.66 Low | Low (high K) | BDL Non-sodic | Low |
| | Site 10 | | | 0-5 | Sandy clay loam | 68 | 2 Unstable | 180.9 Hardsetting | 26.37 Moderate | 12.3 | 6.5 Neutral | 0.199 Slightly saline | 1.02 Medium | Low | BDL Non-sodic | Low |
| | Site 11 | | | 0-5 | Sandy loam | 68 | 3a Moderately stable | 143.8 Hardsetting | 20.60 Moderate | 14.3 | 5.5 Neutral | 0.054 Non-saline | 0.89 Low | Low | BDL Non-sodic | Low |
| Kangaroo Caves area soil 2013 | Site 12 | 0.3 | 47,592 | 0-20 | Sandy loam | 43 | 3b Moderately stable | 9.9 Non-hardsetting | 57.15 Moderate | 17.1 | 5.1 Slightly acidic | 0.057 Non-saline | 1.24 | Low (high K) | BDL Non-sodic | Low |
| | Site 13 | 0.3 | 48,511 | 0-20 | Sandy loam | 47 | 5 Stable | 31.9 Non-hardsetting | 10.55 Moderately slow | - | 6.7 Neutral | 0.033 Non-saline | 0.66 | Low (high K) | BDL Non-sodic | Low (high Ni) |

| Description | Site | Total soil depth (m) | Approx. area of soil present ($m^2$) | Sample depth (cm) | Physical characteristics | | | | | | Chemical characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Soil texture[1] | Coarse material content (%) [2] | Emerson Class [3] | (Modulus of Rupture (kPa) | Hydraulic conductivity (mm/hr) | Upper storage limit (% vol)[4] | pH ($CaCl_2$) | Salinity class (dS/m) | Organic carbon (%) | Nutrient status | Exchangeable Sodium Percentage (%) [5] | Total metal concentrations [6] |
| | Site 14 | 0.5 | 33,940 | 0-20 | Sandy loam | 13 | 5 Stable | 20.1 Non-hardsetting | 54.34 Moderate | 30.7 | 6.6 Neutral | 0.092 Non-saline | 1.47 | Low (high K) | BDL Non-sodic | Low (high Ni) |
| | Site 15 | 0.5 | 20,347 | 0-20 | Sandy loam | 22 | 3b Moderately stable | 15.1 Non-hardsetting | 26.06 Moderate | - | 7.6 Moderately alkaline | 0.142 Non-saline | 0.82 | Low (high K) | BDL Non-sodic | Low (high Ni) |
| Eastern area soil 2013 | Site 16 | 0.7 | No data | 0-20 | Sandy loam | 11 | 8 Stable | 12.1 Non-hardsetting | 122.26 Moderately rapid | 15.2 | 6.7 Neutral | 0.046 Non-saline | 0.62 | Low (high K) | BDL Non-sodic | Low (high Ni) |
| | Site 17 | 0.7 | No data | 0-20 | Sandy loam | 18 | 4 Stable | 11.0 Non-hardsetting | 30.05 Moderate | - | 7.4 Moderately alkaline | 0.059 Non-saline | 0.54 | Low (high K) | BDL Non-sodic | Low (high Ni) |
| Airstrip area soil 2013 | Site 18 | 0.4 | 57,420 | 0-20 | Sandy loam | 17 | 2 Unstable | 34.7 Non-hardsetting | 61.87 Moderate | - | 4.8 Moderately acidic | 0.029 Non-saline | 0.44 | Low (high K) | BDL Non-sodic | Low (high Ni) |
| | Site 19 | 2.0 | 162,974 | 0-20 | Sandy loam | 19 | 2 Unstable | 63.8 Hardsetting | 53.92 Moderate | 19.9 | 7.0 Neutral | 0.029 Non-saline | 0.20 | Low (high K) | BDL Non-sodic | Low (high Ni) |
| | Site 20 | 2.5 | 1,318,360 | 0-20 | Sandy loam | 22 | 2 Unstable | 23.3 Non-hardsetting | 69.27 Moderately rapid | 18.2 | 5.5 Neutral | 0.017 Non-saline | 0.32 | Low (high K) | BDL Non-sodic | Low |

1. Based on the <2 mm size fraction
2. Determined for all coarse fragments >2 mm in size
3. See Appendix C for Emerson Classes. Potentially dispersive properties may be masked by flocculating effects of high salinity
4. Upper storage limit (USL) (% volume) of total material (<2 mm fraction and coarse material)
5. BDL denotes samples for which exchangeable sodium was below the detectable limit - assumed 'non-sodic' (*eCEC < 3 indicating minimal effect on structural decline)
6. 'Low' metal concentrations indicate results below Ecological Investigation Levels (EILs) (Department of Environment 2010)

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# 1. INTRODUCTION

## 1.1 Background

Outback Ecology was commissioned by Venturex Resources Limited (Venturex) to characterise soil resource material and develop a soil resource inventory for the proposed Sulphur Springs Copper Zinc Project (the Project). The Project is located in the Pilbara Region of Western Australia and is situated approximately 110 km south-east of Port Hedland and 57 km west of Marble Bar, within three mining leases: M45/494, M45/653, M45/1001 and seven miscellaneous licences L45/166, L45/170, L45/173, L45/179, L45/188, L45/189 and L45/287 (**Figure 1, Figure 2**).

The Project will comprise the underground development of the Sulphur Springs Copper Zinc deposit, processing of ore at an onsite concentrate plant and haulage of concentrate from Sulphur Springs to Port Hedland via road train for export.

Development within the Project area will include a processing plant, Tailings Storage Facility (TSF), evaporation ponds, a ROM Pad, access roads, workshops, a borrow pit, offices, an accommodation village and an air strip.

The transport route to Port Hedland will be via a haul road, currently under construction by Atlas Iron Limited (Atlas), then along the Marble Bar public road and Great Northern Highway to Port Hedland. The haul road will be shared under an existing agreement with the adjoining Atlas Abydos DSO Project and the construction is not part of the Sulphur Springs Mining Proposal. The haul road is a component of the Atlas Iron Mining Proposal and will not require assessment with this Project.

Copper and zinc concentrate will be produced at an onsite concentrator. The operation is expected to produce around 6,200 wet tonnes (t) of copper concentrate and 5,500 wet t of zinc concentrate per month.

It is proposed that the Project life will be extended by mining at the Venturex owned Whim Creek and Mons Cupri Projects, with the intent for this ore to be hauled by road to Sulphur Springs for processing, as part of the Pilbara Copper Zinc Project.

The tailings in the TSF will be dry stacked and compacted, with the proposed cover design incorporating a clay sealing layer, clean competent waste rock for geotechnical stability and a store-release ‘rocky soil’ layer. The soil cover will require enough volume to store water from the majority of rainfall events, but also be resistant to erosion to allow runoff from high intensity rainfall events.

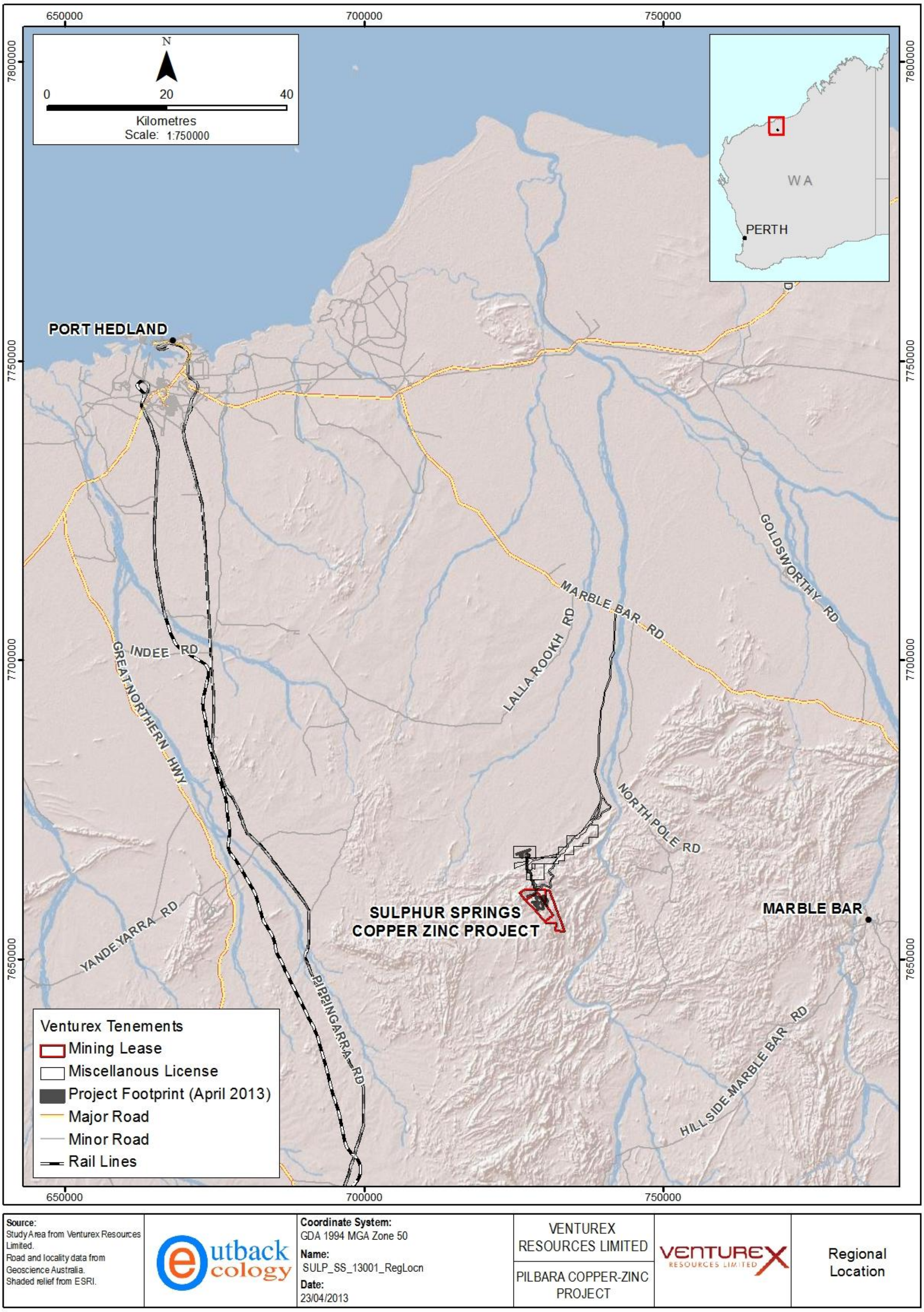


**Figure 1: Regional location of the Sulphur Springs Copper Zinc Project**

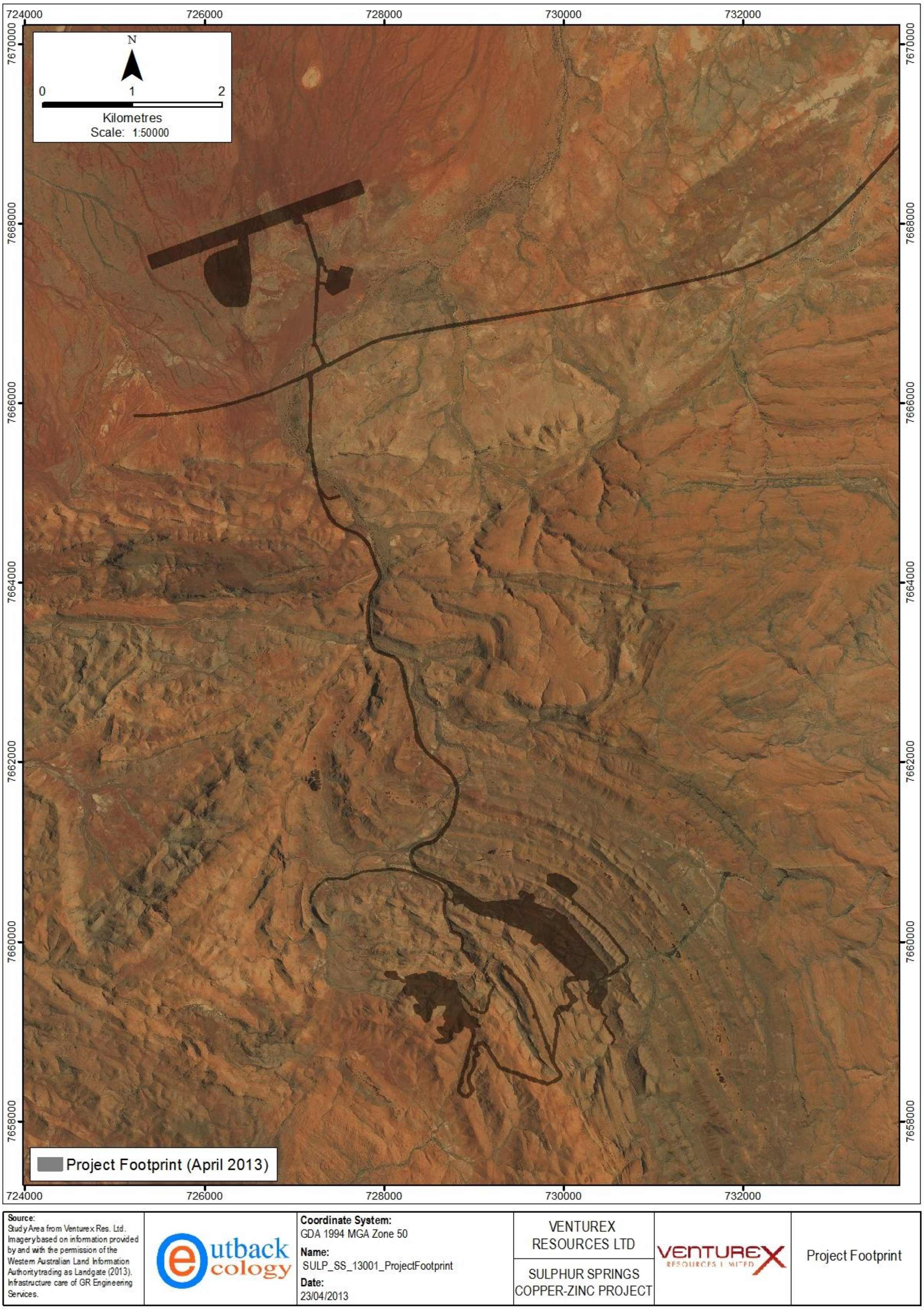


**Figure 2: Proposed Project footprint for the Sulphur Springs Copper Zinc Project**

## 1.2 Climate

The Project area is located within the northern section of the Pilbara bioregion, which experiences a semi-desert to tropical climate characterised by hot summers and relatively warm dry winters (Bureau of Meteorology [BoM] 2012). Tropical cyclones can occur between the months of January to April, bringing sporadic drenching rainfall events (How *et al.* 1991).

The nearest Bureau of Meteorology (BOM) weather station to the Project is located at Marble Bar, approximately 57 km to the east of the Project area. Weather data collected from the Marble Bar Meteorological Station indicates rainfall occurs mainly in the first half of the year with a mean average rainfall of approximately 350 mm (BoM 2012) (**Figure 3**). Rainfall within the Project area can be highly localised and unpredictable with substantial fluctuations occurring from year to year (BoM 2012, Leighton 2004).

Marble Bar typically experiences a very hot summer with the mean maximum temperature reaching 41.6°C in December and the minimum temperature averaging 26.7°C in January (**Figure 3**). Marble Bar averages 98 days above 40° each year (Leighton 2004). Winter occurs from June to August when the mean maximum temperature for Marble Bar is 28°C and the mean minimum temperature is 12.8°C (**Figure 3**).

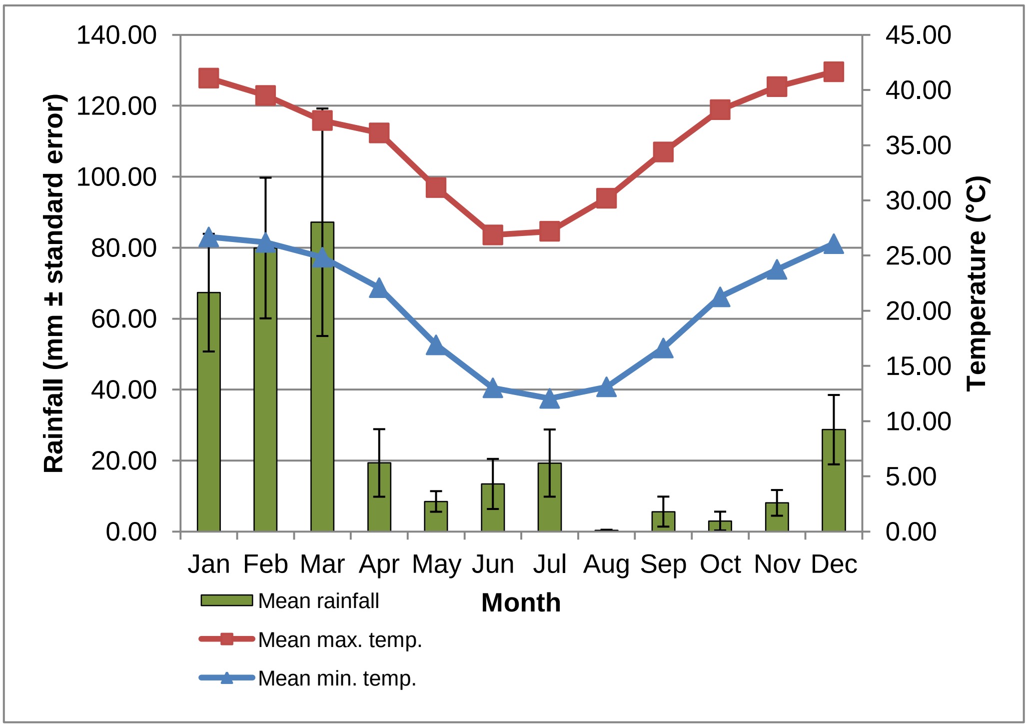


**Figure 3: Long term climate data for Marble Bar Weather Station (BoM 2012)**

### 1.2.1 Average Recurrence Interval

The design rainfall intensity for the Project (position approximately 21.125 S 119.200 E) is recorded in **Table 1** and **Figure 4**. The 1 in 100 year 72 hour rainfall event is 379 mm (BoM 2012).

**Table 1: Sulphur Springs Copper Zinc Project Average Recurrence Interval rainfall intensity over various time periods (millimetres per hour) (BoM 2012)**

| Duration | 1 year | 2 years | 5 years | 10 years | 20 years | 50 years | 100 years |
|---|---|---|---|---|---|---|---|
| 5 Mins | 80.5 | 107 | 152 | 181 | 218 | 267 | 307 |
| 6 Mins | 74.7 | 99.8 | 142 | 169 | 203 | 250 | 287 |
| 10 Mins | 61.5 | 82.4 | 119 | 142 | 171 | 212 | 244 |
| 20 Mins | 46.2 | 62.3 | 91.2 | 110 | 134 | 167 | 194 |
| 30 Mins | 37.8 | 51.2 | 75.8 | 92.1 | 113 | 141 | 164 |
| 1 Hr | 25 | 34.1 | 51.4 | 63.0 | 77.6 | 98.2 | 115 |
| 2 Hrs | 15.1 | 20.8 | 32.0 | 39.7 | 49.4 | 63.1 | 74.3 |
| 3 Hrs | 11.0 | 15.1 | 23.6 | 29.5 | 36.9 | 47.5 | 56.2 |
| 6 Hrs | 6.2 | 8.7 | 13.8 | 17.5 | 22.0 | 28.7 | 34.2 |
| 12 Hrs | 3.6 | 5.0 | 8.1 | 10.4 | 13.2 | 17.3 | 20.8 |
| 24 Hrs | 2.1 | 2.3 | 4.9 | 6.3 | 8.0 | 10.5 | 12.7 |
| 48 Hrs | 1.3 | 1.8 | 2.9 | 3.7 | 4.7 | 6.2 | 7.5 |
| 72 Hrs | 0.9 | 1.3 | 2.0 | 2.6 | 3.3 | 4.4 | 5.3 |

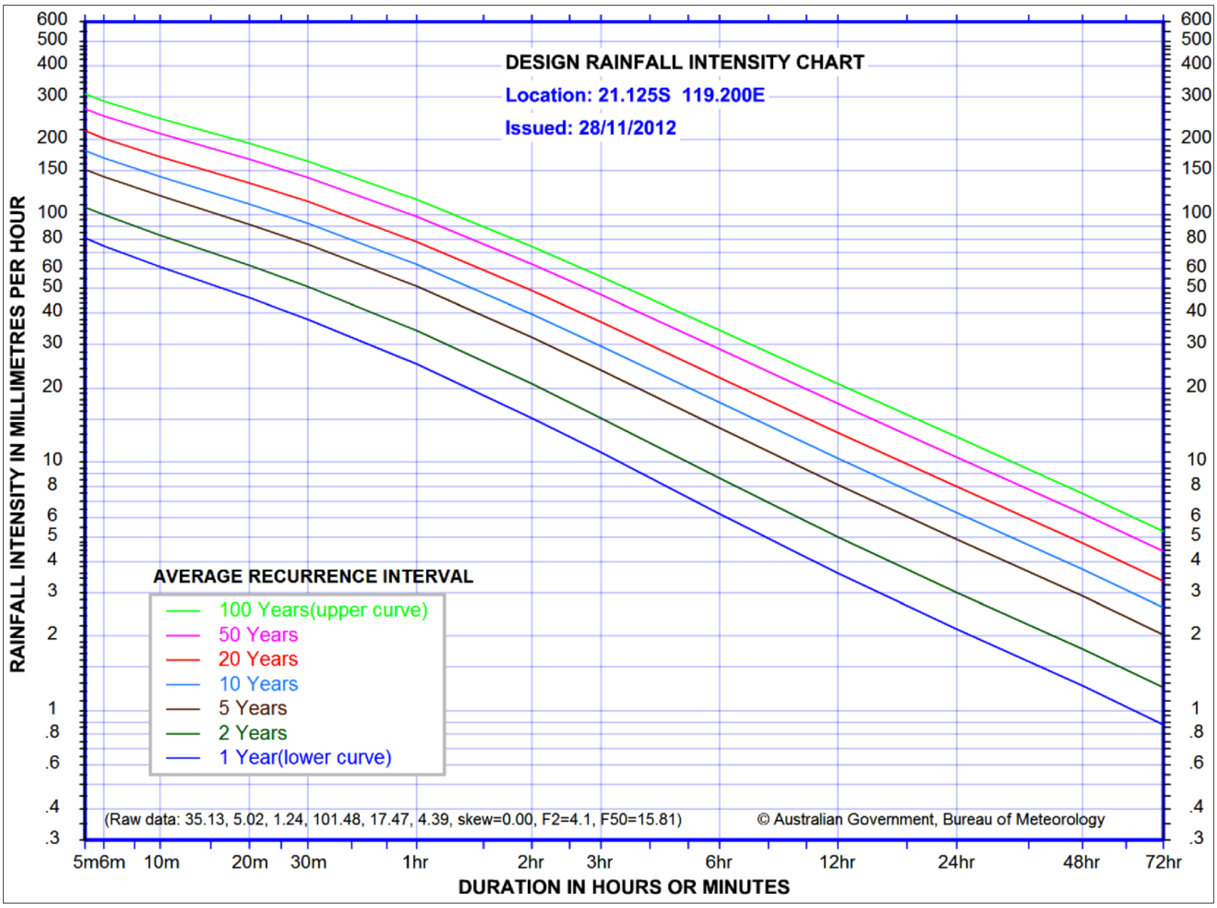


**Figure 4: Sulphur Springs Copper Zinc Project rainfall intensity chart (BoM 2012)**

## 1.3 Geomorphology and Land Systems of the Sulphur Springs Copper Zinc Project Area

The geomorphology of the Sulphur Springs Creek Catchment is characterised by numerous rocky hills and gorges that control the flow of surface water. The Sulphur Springs Project area, including the TSF areas, has a diverse landscape, where the differential weathering of the basement rocks has developed sharp local changes in relief around 175 m (range: 200 to 375 m AHD). In this landscape, the competent lithologies tend to form topologically high areas (such as ridge lines). In contrast, zones subjected to greater geological stress may preferentially weather and erode and be associated with valley-floor settings.

A ferruginous duricrust mantles the upland areas to the south, with pisolitic lags (gravel sized material) common constituents in eroded material. Transported cover (colluvial and alluvial sediments) increases in profile thickness from the upland areas through to valley flanks and floors. These materials are dominated by ferruginised clays and minor iron-stained sand lenses. Topsoil development is localised and not extensive in the Project area.

A regional survey was undertaken in the Pilbara between 1995 and 1999 by the Department of Agriculture (now the Department of Agriculture and Food) and the Department of Land Administration (now Landgate) to develop a comprehensive description of the biophysical resources and the vegetation composition and soil condition within the region. This information was used by van Vreeswyk *et al*. (2004) to classify and map the land systems of the Pilbara region based on landform, soil, vegetation, geology and geomorphology.

An assessment of land systems provides an indication of the occurrence and distribution of landforms and vegetation types within, and surrounding, the Project area. The Project footprint is situated on three land systems: Boolgeeda, Capricorn and Rocklea (**Table 2, Figure 5**).

**Table 2: Land systems within and surrounding the Project area**

| Land System | Characteristics | Area in Project Footprint |
|---|---|---|
| Boolgeeda | Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands or mulga shrublands | 63.7 ha (39%) |
| Capricorn | Hills and ridges of sandstone and dolomite supporting low shrublands or shrubby spinifex grasslands | 74.0 ha (46%) |
| Rocklea | Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands | 25.0 ha (15%) |

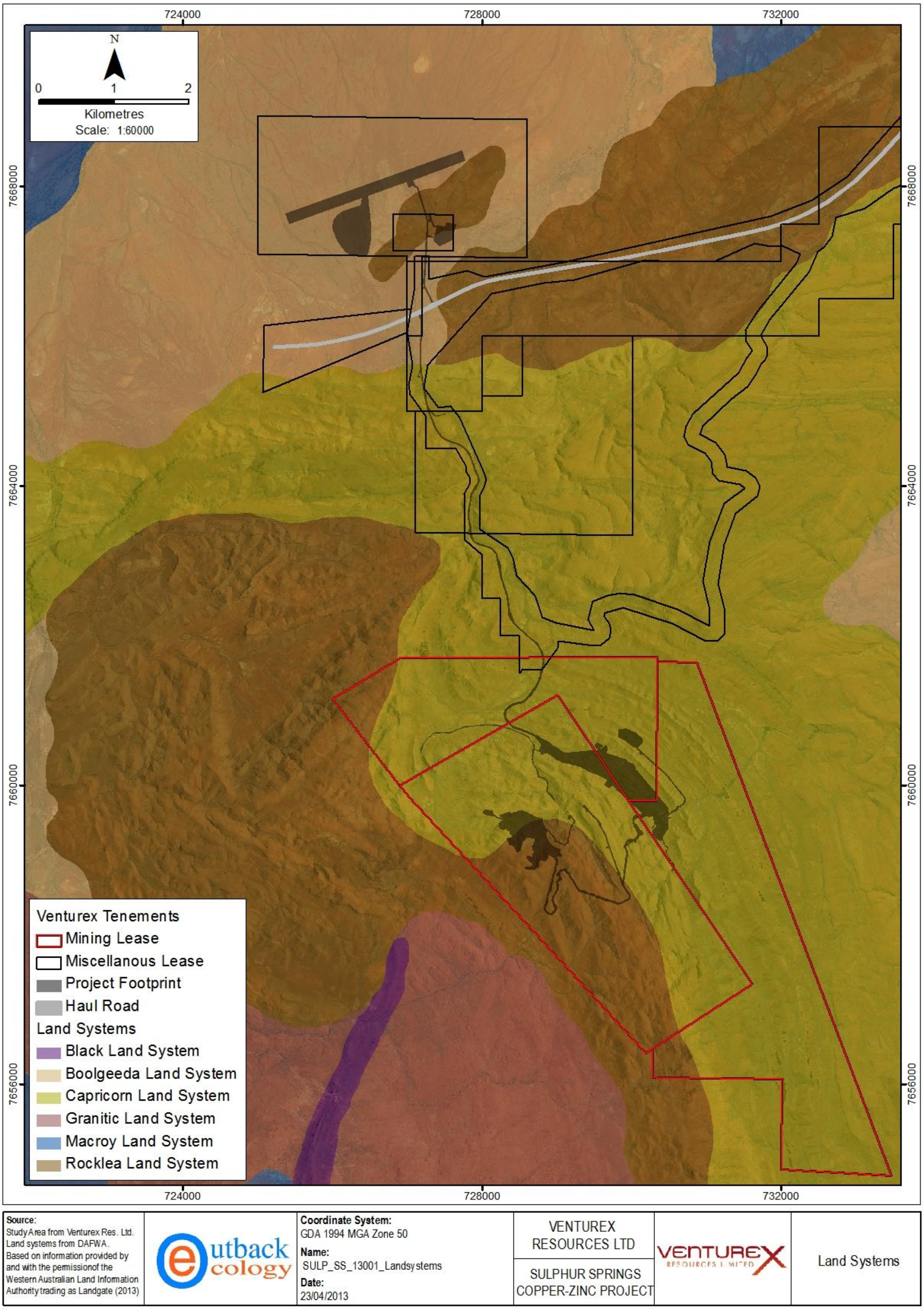


**Figure 5: Land Systems within the Sulphur Springs Copper Zinc Project**

### 1.4 Geology

The Sulphur Springs Copper Zinc Project Area is located in the East Pilbara Terrane, the oldest component of the northern Pilbara Craton with a maximum thickness up to 22,000 m. The East Pilbara Terrane is a 'dome-and-basin' granite–greenstone domain in which ovoid granites are flanked by arcuate-shaped volcano-sedimentary packages. Within the Sulphur Springs Copper Zinc Project area, the geology predominantly consists of successions of the Sulphur Springs Group. Sulphur Springs encompasses several deposits of volcanogenic massive sulphide (VMS) copper-zinc mineralisation occurring within a 35 km long belt of mineralised volcanic rocks.

The Sulphur Springs orebody is a strata-bound copper-zinc rich massive sulphide lens extending approximately 500 m east-west along strike, and for a similar distance down dip, and is up to 50 m thick in places. The orebody is underlain by a copper rich stringer zone which is far more variable, though typically it is between 2 m and 50 m thick, dipping moderately towards the north at about 50 degrees. Mineralisation appears to migrate from the felsic volcanic Marker Chert contact in the west and central parts of the deposit to the upper part of the Marker Chert in the east of the deposit. This is interpreted to be a post mineralisation structural phenomenon rather than a primary emplacement feature. Mineralisation is generally zoned from copper dominant at the base, to zinc rich at the top, of the deposit. The contact between the chert and the top of the massive sulphide ore is generally sharply defined while the lower contact to the underlying stringer zone is more gradational (Venturex 2012).

### 1.5 Report scope and objectives

The aim of the sampling and analysis programme was to assess soil resources from the Project area which may be available for use as a rehabilitation medium and / or as a component of the proposed cover for the TSFs. This report details the physical and chemical characteristics of soil materials within the Project area and discusses their suitability for use as a component of the TSF cover. Also included is a soil resources inventory detailing the locations, characteristics and potential volumes of soil resources identified (by Venturex personnel) within the Project area.

The likely closure design for the TSFs will incorporate a soil cover which is capable of storing water from the majority or rainfall events, but sheds water from high intensity storms. The store- release soil layer therefore needs to be 'rocky' enough to withstand erosional forces during high intensity rainfall events, but have enough soil sized fraction material to hold and release water via evaporation and transpiration.

This report documents the results of the soil characterisation and provides the following:

- descriptions of soil profile morphology, to the maximum depth possible, based on Australian Soil Classification Standards (McDonald *et al.* 1998);
- soil physical parameters
    - soil texture / particle size distribution (PSD);

  - % coarse material (>2 mm);
  - structural stability assessed via Emerson Aggregate Test;
  - hardsetting / strength of disturbed material assessed via modulus of rupture (MOR) test;
  - saturated hydraulic conductivity ($K_{sat}$) (repeated for several wetting / drying cycles); and
  - water retention characteristics of selected representative samples.
- soil chemical characteristics
  - soil pH and electrical conductivity (EC);
  - plant-available nutrients (N, P, K, S) and soil organic carbon (C) of selected samples;
  - exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$), derivation of exchangeable sodium percentage (ESP), and
  - total metal concentrations (As, Cd, Cr, Cu, Pb, Ni, Zn and Hg).

# 2. MATERIALS AND METHODS

## 2.1 Sampling regime

The field surveys were conducted in December 2011, November 2012 and February 2013 by Venturex personnel. Topsoil and subsoil materials were collected from areas identified by Venturex geologists as having potentially substantial soil resources. A total of 41 samples, from 26 sites, were received from site along with photographs and information (2012 and 2013 only) derived from the soil sampling sites.

The sampling undertaken in 2011 provided 16 topsoil and subsoil samples from 6 sites (Sites A1 to A6); the 2012 sampling provided 16 topsoil and subsoil samples from 11 sites (Sites 1 to 11); and the 2013 sampling provided nine topsoil and subsoil samples from nine sites within the Project area. The samples were taken from various depth intervals to a maximum of 250 cm (**Table 3**, **Figure 6**, **Figure 7, Figure 8, Figure 9**) and analysed for chemical and physical parameters. The 2012 and 2013 surface soils were described (soil profile morphology, soil structure, root distribution) based on the Australian Soil and Land Survey Handbook (McDonald *et al.* 1998). The 2012 and 2013 field surveys also included an estimation, by Venturex personnel, of potential soil resource areas and depths of soil located at Sites 1 to 20 (**Figure 6**, **Figure 7, Figure 8, Figure 9**).

**Table 3: Summary table of sampling sites and locations for the Sulphur Springs Copper Zinc Project**

| Description | Site # | Sample ID | Sample depth (cm) | Coordinates (Projection: MGA Zone 50; Datum: GDA94) | |
|---|---|---|---|---|---|
| | | | | Easting (mE) | Northing (mN) |
| Project area soil 2011 | Site A1 | SSA01 | 0-5 | - | - |
| | | SSA01 | 10-20 | - | - |
| | | SSA01 | 40-50 | - | - |
| | Site A2 | SSA02 | 0-5 | - | - |
| | | SSA02 | 10-20 | - | - |
| | | SSA02 | 40-50 | - | - |
| | Site A3 | SSA03 | 0-5 | - | - |
| | | SSA03 | 10-20 | - | - |
| | | SSA03 | 40-50 | - | - |
| | Site A4 | SSA04 | 0-5 | - | - |
| | | SSA04 | 10-20 | - | - |
| | | SSA04 | 40-50 | - | - |
| | Site A5 | SSA05 | 0-5 | - | - |
| | | SSA05 | 10-20 | - | - |
| | Site A6 | SSA06 | 0-5 | - | - |
| | | SSA06 | 10-20 | - | - |
| Project area soil 2012 | Site 1 | SS01 | 0-20 | 730335 | 7659666 |
| | | SS01 | 40-60 | 730335 | 7659666 |
| | Site 2 | SS02 | 0-20 | 729729 | 7659988 |
| | Site 3 | SS03 | 0-20 | 729455 | 7660265 |
| | | SS03 | 40-60 | 729455 | 7660265 |
| | Site 4 | SS04 | 0-20 | 728647 | 7660639 |
| | Site 5 | SS05 | 0-20 | 728070 | 7660962 |
| | | SS05 | 40-60 | 728070 | 7660962 |
| | | SS05 | 100-120 | 728070 | 7660962 |
| | Site 6 | SS06 | 0-20 | 728575 | 7661116 |
| | | SS06 | 40-60 | 728575 | 7661116 |
| TSF Area B footprint soil 2012 | Site 7 | SS07 | 0-5 | 728880 | 7659229 |
| | Site 8 | SS08 | 0-5 | 728808 | 7659105 |
| TSF Area A footprint soil 2012 | Site 9 | SS09 | 0-5 | 728728 | 7659352 |
| | Site 10 | SS10 | 0-5 | 728566 | 7659440 |
| | Site 11 | SS11 | 0-5 | 728385 | 7659517 |
| Kangaroo Caves area soil 2013 | Site 12 | SS12 | 0-20 | 734025 | 7651760 |
| | Site 13 | SS13 | 0-20 | 733791 | 7653547 |

| Description | Site # | Sample ID | Sample depth (cm) | Coordinates (Projection: MGA Zone 50; Datum: GDA94) | |
|---|---|---|---|---|---|
| | | | | Easting (mE) | Northing (mN) |
| | Site 14 | SS14 | 0-20 | 733561 | 7654330 |
| | Site 15 | SS15 | 0-20 | 732769 | 7655219 |
| Eastern area soil 2013 | Site 16 | SS16 | 0-20 | 732292 | 7658966 |
| | Site 17 | SS17 | 0-20 | 731305 | 7661016 |
| Airstrip area soil 2013 | Site 18 | SS18 | 0-20 | 726432 | 7667050 |
| | Site 19 | SS19 | 0-20 | 727040 | 7666769 |
| | Site 20 | SS20 | 0-20 | 726398 | 7667110 |

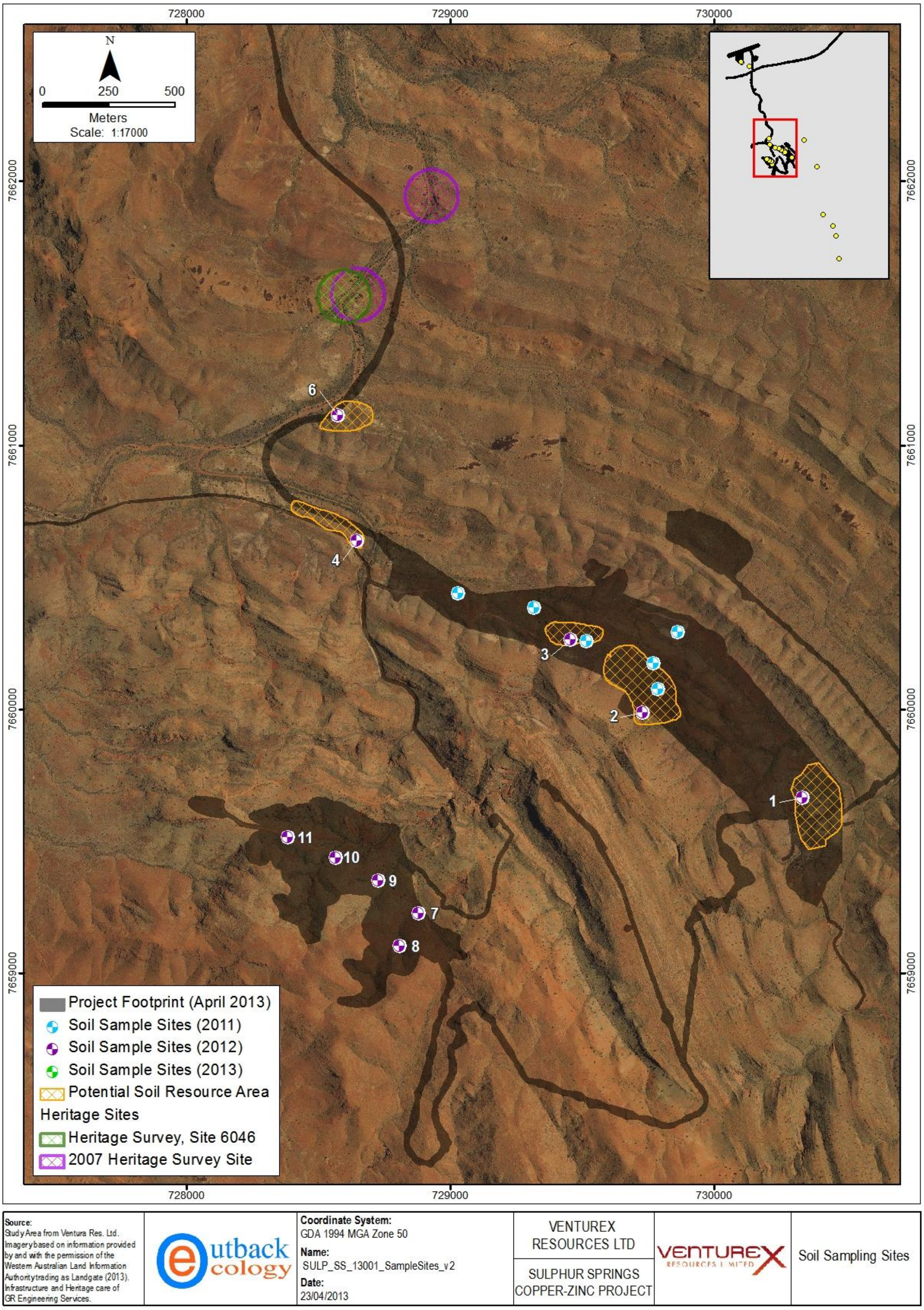


**Figure 6: Location of 2011 and 2012 sampling sites and potential soil resources at the Sulphur Springs Copper Zinc Project**

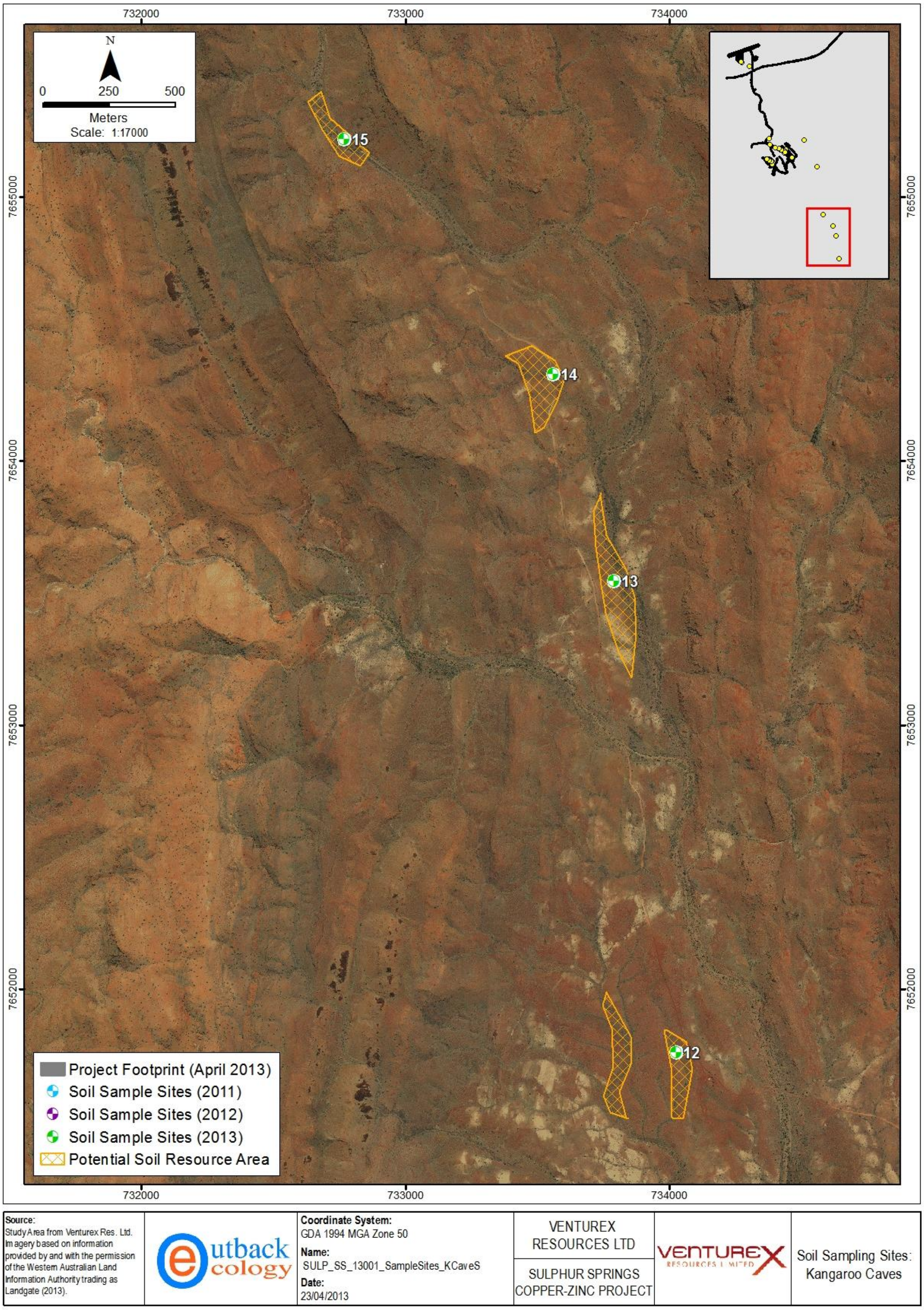


**Figure 7: Location of Kangaroo Caves area 2013 sampling sites and potential soil resources at the Sulphur Springs Copper Zinc Project**

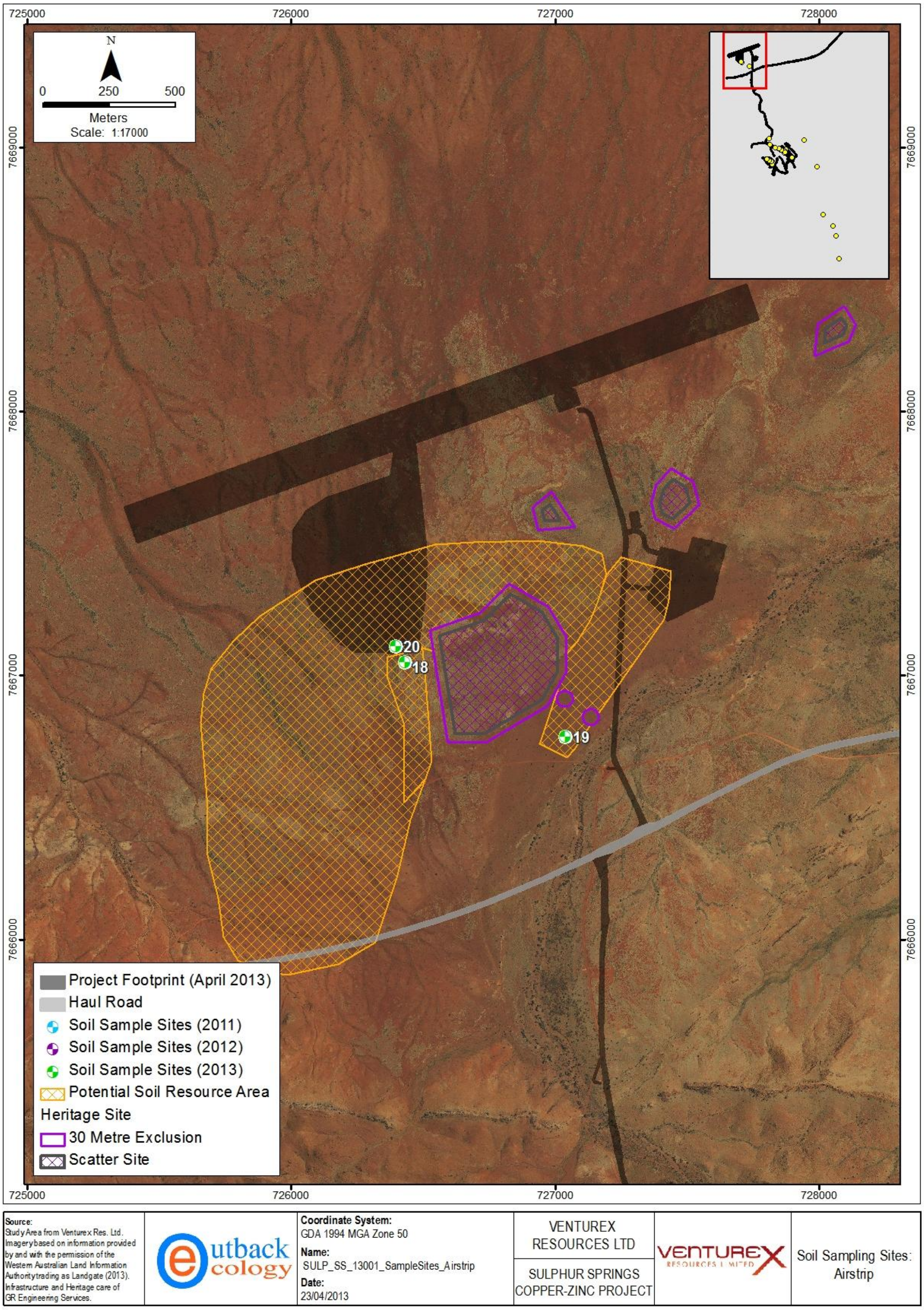


**Figure 8: Location of Air Strip area 2013 sampling sites and potential soil resources at the Sulphur Springs Copper Zinc Project**


**Figure 9: Location of Eastern area 2013 sampling sites at the Sulphur Springs Copper Zinc Project**

### 2.2 Test work and procedures

CSBP Soil and Plant Laboratory conducted analyses on the sampled soils from the 26 sites for ammonium and nitrate (Scarle 1984), plant-available phosphorus and potassium (Colwell 1965, Rayment and Higginson 1992), plant-available sulphur (Blair *et al.* 1991) and organic carbon (Walkley and Black 1934). Measurements of electrical conductivity (1:5 $H_2O$) and soil pH (1:5 $H_2O$ and 1:5 $CaCl_2$) were conducted using the methods described in Rayment and Higginson (1992). Exchangeable cations $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ (Rayment and Higginson 1992) and particle size distribution (McKenzie *et al.* 2002) was also assessed on selected samples.

ALS Environmental Laboratory analysed selected samples for total concentrations of metals including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), zinc (Zn) and mercury (Hg). Cold vapour/ flow injection mercury system (CV/FIMS) method was used to analyse for Hg, while inductively coupled plasma atomic emission spectroscopy (ICP-AES) method was used for the other elements.

Soil texture was assessed by Outback Ecology staff using the procedure described in McDonald *et al.* (1998). A measure of soil slaking and dispersive properties (Emerson Aggregate Test) was conducted as described in McKenzie *et al.* (2002). Soil strength and the resulting tendency of each material to hardset was assessed by OES staff using a modified Modulus of Rupture (MOR) test (Aylmore and Sills 1982, Harper and Gilkes 1994). Saturated hydraulic conductivity of the soils was assessed on ‘loosely’ re-packed samples (Hunt and Gilkes 1992).

The water retention characteristics of all 2012 and 2013 samples were assessed by Outback Ecology using pressure plate apparatus, as described in McKenzie *et al.* (2002). Samples assessed using the pressure plate apparatus were packed to a bulk density likely to be experienced once the materials are disturbed and re-deposited, approximately 75% of the maximum dry bulk density.

**Table 4: Soil analyses conducted on soil samples from the Sulphur Springs Copper Zinc Project**

| Soil parameter | Measurement method | Conducted by | Number of samples analysed | Sample selection criteria |
|---|---|---|---|---|
| ***Chemical properties*** | | | | |
| Total Metals (As, Cd, Cr, Cu, Pb, Ni and Zn) | Inductively coupled plasma atomic emission spectroscopy (ICP-AES) method | ALS | 10 + 16 + 9 | Selected 2011 and all 2012 and 2013 samples |
| Total Metals (Hg) | Cold vapour/ Flow injection mercury system (CV/FIMS) method | ALS | 10 + 16 + 9 | Selected 2011 and all 2012 and 2013 samples |
| Soil pH | pH measured in 1:5 soil:water and 1:5 Soil:$CaCl_2$ (Rayment and Higginson 1992) | CSBP | 16 + 16 + 9 | All samples |
| Electrical conductivity | Measured in 1:5 soil:water (Rayment and Higginson 1992) | CSBP | 16 + 16 + 9 | All samples |
| Plant-available nitrogen (ammonium and nitrate) | Scarle (1984) | CSBP | 16 + 16 + 9 | All samples |
| Exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$) | Rayment and Higginson (1992) | CSBP | 16 + 16 + 9 | All samples |
| Plant-available phosphorus and potassium | Colwell (1965); Rayment and Higginson (1992) | CSBP | 16 + 16 + 9 | All samples |
| Plant-available sulphur | Blair *et al.* (1991) | CSBP | 16 + 16 + 9 | All samples |
| Organic carbon percentage | Walkley and Black (1934) | CSBP | 16 + 16 + 9 | All samples |
| ***Physical properties*** | | | | |
| Particle size distribution | Pipette method (Day, 1965) | CSBP | 3 + 16 + 9 | Selected 2011 and all 2012 and 2013 samples |
| Saturated hydraulic conductivity ($K_{sat}$) | Measured on materials packed to their respective field bulk densities, using a constant-head of pressure technique (Hunt and Gilkes 1992) | Outback Ecology | 6 + 16 + 9 | Selected 2011 and all 2012 and 2013 samples |
| Soil slaking and dispersive properties | Emerson Aggregate Test (McKenzie *et al.*, 2002) | Outback Ecology | 16 + 16 + 9 | All samples |
| Soil strength | Modified Modulus of Rupture test (Aylmore and Sills 1982; Harper and Gilkes 1994) | Outback Ecology | 16 + 16 + 9 | All samples |
| Soil texture | McDonald *et al.* (1998) | Outback Ecology | 16 + 16 + 9 | All samples |

| Soil parameter | Measurement method | Conducted by | Number of samples analysed | Sample selection criteria |
|---|---|---|---|---|
| Soil colour | Determined using a Munsell® soil colour chart | Outback Ecology | 16 + 16 + 9 | All samples |
| Water retention characteristics | Using pressure plate apparatus (McKenzie *et al.* 2002) | Outback Ecology | 16 + 9 | All 2012 and 2013 samples |

# 3. RESULTS AND DISCUSSION

## 3.1 Soil profile descriptions

Photographs of the 2011 Project area sites (Site A1 to A6) were provided by Venturex personnel (**Section 3.1.1** to **3.1.6**). A description of the soil profile morphology and vegetation at each of the sites, sampled in 2012 and 2013, has been documented from photographs and information supplied by Venturex personnel (**Section 3.1.7** to **3.1.26**). Individual physical and chemical characteristics of all soil samples are then discussed in further detail (**Sections 3.2** to **3.5**).

### 3.1.1 Site A1 (2011 soil sampling)

**Plate 1: Vegetation and soil surface at Site A 1**

### 3.1.2 Site A2 (2011 soil sampling)

**Plate 2: Vegetation and soil surface at Site A 2**

### 3.1.3 Site A3 (2011 soil sampling)

**Plate 3: Vegetation and soil surface at Site A 3**

### 3.1.4 Site A4 (2011 soil sampling)

**Plate 4: Vegetation and soil surface at Site A 4**

### 3.1.5 Site A5 (2011 soil sampling)

**Plate 5: Vegetation and soil surface at Site A 5**

### 3.1.6 Site A6 (2011 soil sampling)

**Plate 6: Vegetation and soil surface at Site A 6**

### 3.1.7 Site 1 (2012 soil sampling)

**Plate 7: Soil profile at Site 1**

*Soil profile description*

*0 – 20 cm:* Approximately 20% angular coarse siltstone fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as 'few'.

*20 – 70 cm:* Approximately 50% angular coarse siltstone fragments, 20 to 150 mm in size. Root abundance classified as 'few'.

*70 cm:* Siltstone bedrock.

**Plate 8: Vegetation at Site 1**

*Soil surface:* Approximately 60% coarse shale fragments. No crusting, leaf litter or erosion.

*Vegetation:* Burnt spinifex and shrubs.

#### 3.1.8 Site 2 (2012 soil sampling)

**Plate 9: Soil profile at Site 2**

*Soil profile description*

*0 – 40 cm:* Approximately 50% rounded coarse sandstone fragments, 30 to 150 mm in size. Root abundance classified as ‘few’.

*40 cm:* Sandstone bedrock.

**Plate 10: Vegetation at Site 2**

*Soil surface:* Approximately 60 % coarse sandstone fragments. No crusting, leaf litter or erosion.

*Vegetation:* Burnt spinifex.

### 3.1.9 Site 3 (2012 soil sampling)

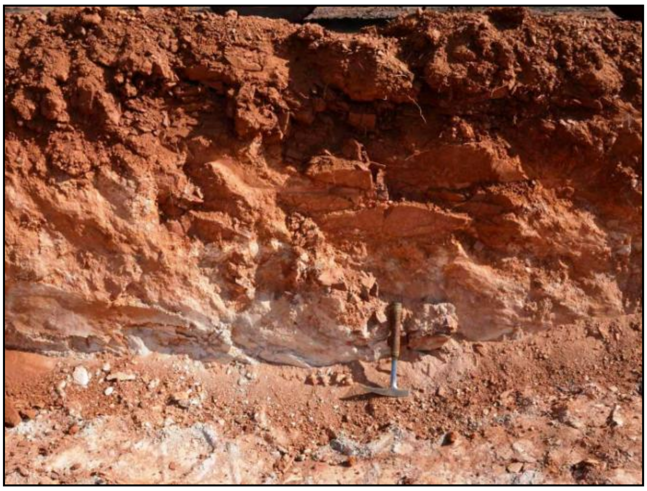

**Plate 11: Soil profile at Site 3**

*Soil profile description*

*0 – 30 cm:* Approximately 10% angular coarse siltstone fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as 'common'.

*30 – 100 cm:* Approximately 10% angular coarse siltstone fragments, 30 to 50 mm in size. Aggregates present. Root abundance classified as 'few'.

*100 cm:* Siltstone bedrock.

**Plate 12: Vegetation at Site 3**

*Soil surface:* Approximately 60% coarse siltstone and sandstone fragments. No crusting, leaf litter or erosion.

*Vegetation:* Burnt spinifex.

### 3.1.10 Site 4 (2012 soil sampling)

Plate 13: Soil profile at Site 4

*Soil profile description*

*0 – 40 cm:* Approximately 50% angular coarse chert and sandstone fragments, 30 to 100 mm in size. Aggregates present. Root abundance classified as ‘few’.

*40 cm:* Chert and sandstone bedrock.

Plate 14: Vegetation at Site 4

*Soil surface:* Approximately 50% coarse sandstone and siltstone fragments. No crusting, leaf litter or erosion.

*Vegetation:* Burnt spinifex and shrubs.

### 3.1.11 Site 5 (2012 soil sampling)

**Plate 15: Soil profile at Site 5**

*Soil profile description*

*0 – 40 cm:* Approximately 10% rounded coarse siltstone and sandstone fragments, 30 to 40 mm in size. Aggregates present. Root abundance classified as 'many'.

*40 – 110 cm:* Approximately 10% rounded coarse siltstone and sandstone fragments, 30 to 40 mm in size. Aggregates present. Root abundance classified as 'few'.

*110 – 120 cm:* Approximately 50% angular coarse dolerite fragments, 50 to 150 mm in size. Aggregates present. Root abundance classified as 'none'.

*120 cm:* Dolerite bedrock.

**Plate 16: Vegetation at Site 5**

*Soil surface:* Approximately 10% coarse sandstone and siltstone fragments. No crusting or leaf litter. Drainage line present.

*Vegetation:* Burnt spinifex and gumtrees.

3.1.12 Site 6 (2012 soil sampling)

Plate 17: Soil profile at Site 6

*Soil profile description*

*0 – 100 cm:* Approximately 50% angular coarse siltstone fragments, 20 to 50 mm in size. Aggregates present. Root abundance classified as ‘few’.

*100 cm:* Siltstone bedrock.

Plate 18: Vegetation at Site 6

*Soil surface:* Approximately 90% coarse siltstone fragments. No crusting, leaf litter or erosion.

*Vegetation:* Burnt spinifex and small trees.

### 3.1.13 Site 7 (2012 soil sampling)

**Plate 19: Soil profile at Site 7**

*Soil profile description*

*0 – 5 cm:* Approximately 40% angular coarse dacite fragments, 30 to 100 mm in size. Root abundance classified as 'few'.

*5 cm:* Dacite bedrock

*Soil surface:* No crusting, leaf litter or erosion.

*Vegetation:* Spinifex

### 3.1.14 Site 8 (2012 soil sampling)

**Plate 20: Soil profile at Site 8**

*Soil profile description*

*0 – 5 cm:* Approximately 70% angular coarse dacite fragments, 20 to 100 mm in size. Root abundance classified as 'few'.

*5 cm:* Dacite bedrock

*Soil surface:* No crusting, leaf litter or erosion..

*Vegetation:* Spinifex and shrubs.

### 3.1.15 Site 9 (2012 soil sampling)

**Plate 21: Soil profile at Site 9**

*Soil profile description*

*0 – 5 cm:* Approximately 70% angular coarse dacite fragments, 20 to 50 mm in size. Aggregates present. Root abundance classified as 'few'.

*5 cm:* Dacite bedrock

*Soil surface:* No crusting, leaf litter or erosion..

*Vegetation:* Spinifex and small trees.

### 3.1.16 Site 10 (2012 soil sampling)

**Plate 22: Soil profile at Site 10**

*Soil profile description*

*0 – 5 cm:* Approximately 80% angular coarse dacite fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as 'few'.

*5 cm:* Dacite bedrock

*Soil surface:* No crusting, leaf litter or erosion.

*Vegetation:* Burnt spinifex and trees.

### 3.1.17 Site 11 (2012 soil sampling)

**Plate 23: Soil profile at Site 11**

*Soil profile description*

*0 – 5 cm:* Approximately 80% angular coarse dacite and rhyolite fragments, 20 to 100 mm in size. Root abundance classified as 'none'.

*5 cm:* Dacite bedrock

*Soil surface:* No crusting, leaf litter or erosion.

*Vegetation:* None.

### 3.1.18 Site 12 (2013 soil sampling)

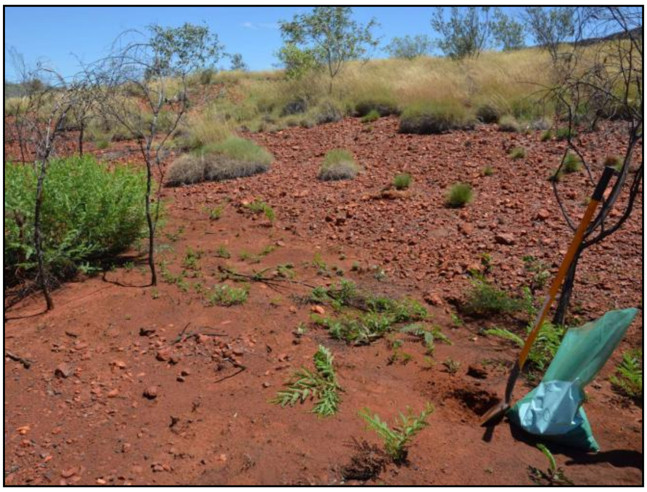

**Plate 24: Soil profile at Site 12**

*Soil profile description*

*0 – 20 cm:* Approximately 40% angular coarse fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as 'few'.

*20 – 30 cm:* Unknown

*Soil surface:* Approximately 50% coarse fragments. No crusting or leaf litter. Creek bed erosion evident.

*Vegetation:* Spinifex and small trees.

### 3.1.19 Site 13 (2013 soil sampling)

**Plate 25: Soil profile at Site 13**

*Soil profile description*

*0 – 20 cm:* Approximately 45% angular coarse fragments, 20 to 30 mm in size. Aggregates present. Root abundance classified as ‘few’.

*20 – 30 cm:* Unknown

*Soil surface:* Approximately 50% coarse fragments. No crusting, leaf litter or erosion.

*Vegetation:* Abundant spinifex.

### 3.1.20 Site 14 (2013 soil sampling)

**Plate 26: Soil profile at Site 14**

*Soil profile description*

*0 – 20 cm:* Approximately 10% coarse fragments. Aggregates present. Root abundance classified as ‘few’.

*20 – 50 cm:* Unknown

*Soil surface:* Approximately 20% coarse fragments. No crusting, leaf litter or erosion.

*Vegetation:* Spinifex and small trees.

### 3.1.21 Site 15 (2013 soil sampling)

**Plate 27: Soil profile at Site 15**

*Soil profile description*

*0 – 20 cm:* Approximately 20% coarse fragments. Aggregates present. Root abundance classified as 'few'.

*20 – 50 cm:* Unknown

*Soil surface:* Approximately 30% coarse fragments. No crusting or leaf litter. Erosion evident in possible water course.

*Vegetation:* Spinifex and small trees.

### 3.1.22 Site 16 (2013 soil sampling)

**Plate 28: Soil profile at Site 16**

*Soil profile description*

*0 – 20 cm:* Approximately 10% coarse fragments. Aggregates present. Root abundance classified as 'few'.

*20 – 70 cm:* Unknown

*Soil surface:* Approximately 20% coarse fragments. No crusting or leaf litter. Minor erosion evident.

*Vegetation:* Small burned trees.

### 3.1.23 Site 17 (2013 soil sampling)

**Plate 29: Soil profile at Site 17**

*Soil profile description*

*0 – 20 cm:* Approximately 20% coarse fragments. Aggregates present. Root abundance classified as 'few'.

*20 – 70 cm:* Unknown

*Soil surface:* Approximately 50% coarse fragments. No crusting or leaf litter. Minor erosion evident.

*Vegetation:* Small trees and spinifex.

### 3.1.24 Site 18 (2013 soil sampling)

**Plate 30: Soil profile at Site 18**

*Soil profile description*

*0 – 20 cm:* Approximately 15% coarse fragments. Aggregates present. Root abundance classified as 'few'.

*20 – 40 cm:* Unknown

*Soil surface:* Approximately 10% coarse fragments. No crusting leaf litter or erosion.

*Vegetation:* Small trees.

### 3.1.25 Site 19 (2013 soil sampling)

**Plate 31: Soil profile at Site 19**

*Soil profile description*

*0 – 20 cm:* Approximately 20% coarse fragments. Aggregates present. Root abundance classified as 'none'.

*20 – 200 cm:* Unknown

*Soil surface:* Approximately 5% coarse fragments. No crusting, leaf litter or erosion.

*Vegetation:* Dispersed small spinifex.

### 3.1.26 Site 20 (2013 soil sampling)

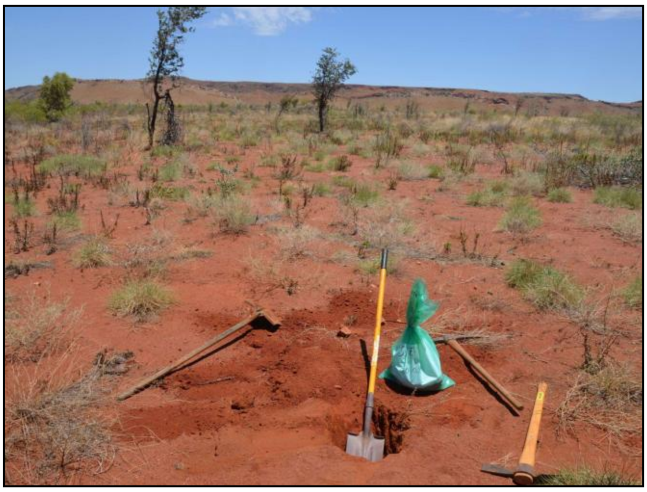

**Plate 32: Soil profile at Site 20**

*Soil profile description*

*0 – 20 cm:* Approximately 20% coarse fragments. Aggregates present. Root abundance classified as 'none'.

*20 – 250 cm:* Unknown

*Soil surface:* Approximately 5% coarse fragments. No crusting, leaf litter or erosion.

*Vegetation:* Dispersed spinifex and grass.

## 3.2 Soil physical properties – Project area sites - 2011 and 2012

### 3.2.1 Soil profile morphology

The surface soil profiles investigated within the 2011 and 2012 Project area sites, exhibited some variation in terms of morphological characteristics. All soil profiles present were typically shallow, with fractured / competent bedrock present at all 2012 sites. Fractured bedrock typically occurred within 5 cm of the surface within the TSF footprint sites. The depth to competent rock ranged from approximately 40 to 120 cm at the other 2012 sampling sites.

### 3.2.2 Soil texture

Soil texture describes the proportions of sand, silt and clay (the particle size distribution) within a soil. The particle size distribution and resulting textural class of soils is an important factor influencing most physical and many chemical and biological properties. Soil structure, water holding capacity, hydraulic conductivity, soil strength, fertility, erodibility and susceptibility to compaction are some of the factors closely linked to soil texture.

Particle size distribution results indicate that the texture of the soil sized fraction (<2 mm) ranged from ‘loamy sand’ to ‘sandy clay’ (**Figure 10**). The clay fraction within the samples was variable, ranging from 4.8% of the soil sized fraction (<2 mm) for the sub surface soils from Site 5, to 29.0% of the soil from Site 6. The amount of coarse material present (>2 mm) within the soil samples was variable, ranging from 28% to 81%, but typically high, with the majority of soils having greater than 50% coarse material content (**Figure 11**).

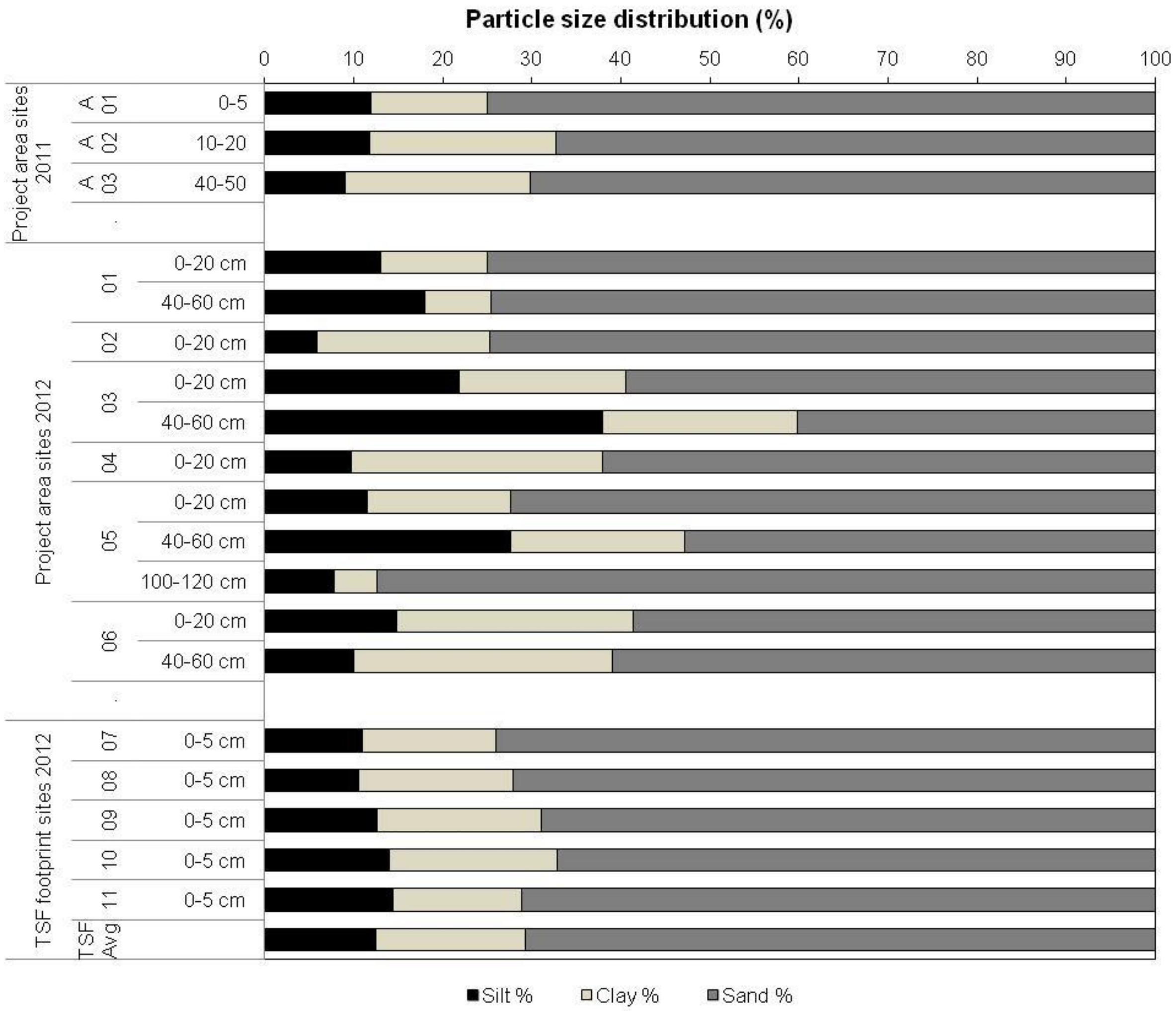


**Figure 10: Individual particle size distribution (%) for soil samples (<2 mm fraction) from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites**

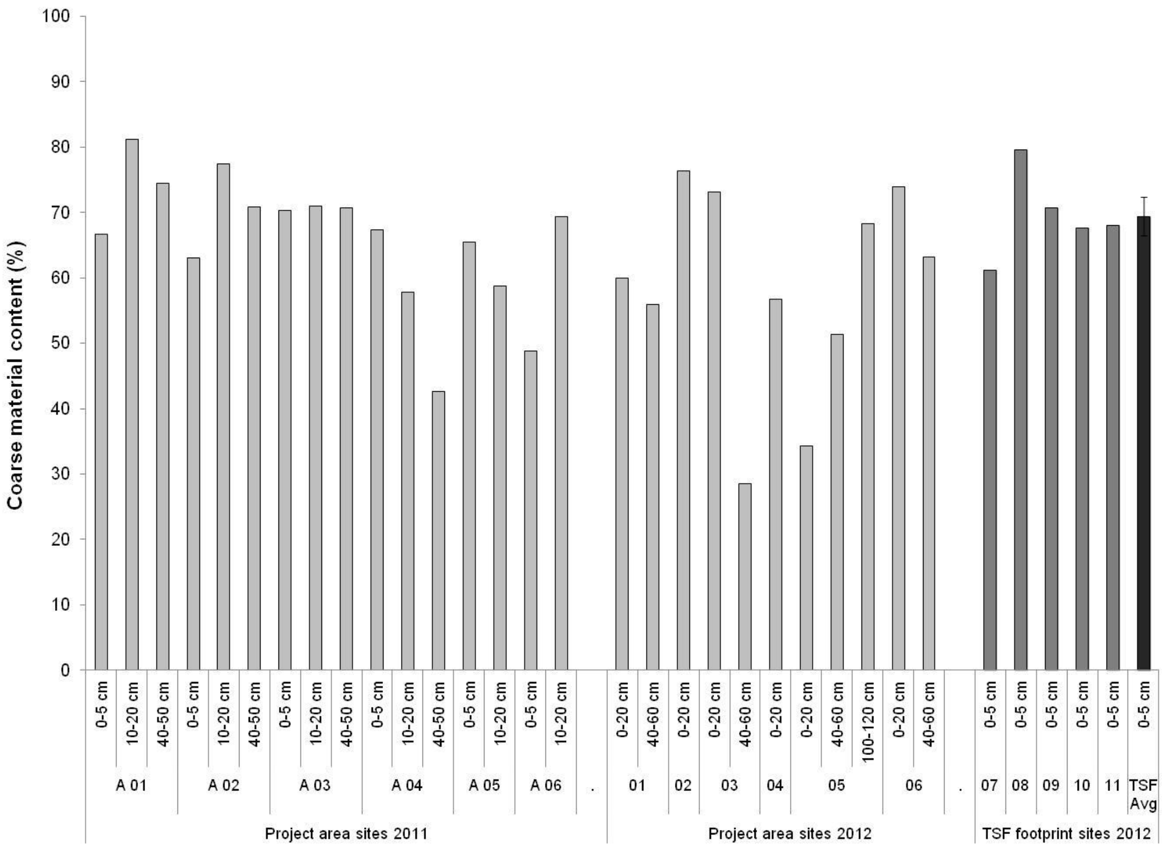


**Figure 11: Individual coarse material content (%) (>2 mm fraction) for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)**

### 3.2.3 Soil structure

Soil structure describes the arrangement of solid particles and void space in a soil. It is an important factor influencing the ability of soil to support plant growth, store and transmit water and resist erosional processes. A well-structured soil is one with a range of different sized aggregates, with component particles bound together to give a range of pore sizes facilitating root growth and the transfer of air and water.

Soil structure can be influenced by the particle size distribution, chemical composition and organic matter content of a soil, and is often affected by root growth, vehicle compaction, and with respect to reconstructed soil profiles, the methods of soil handling and deposition. When a soil material is disturbed, the breakdown of aggregates into primary particles can lead to structural decline (Needham *et al.* 1998). This can result in hard-setting and crusting at the soil surface and a 'massive' soil structure at depth, potentially reducing the ability of seeds to germinate, roots to penetrate the soil matrix and water to infiltrate to the root zone.

The soils sampled from the proposed TSF footprints were predominantly single grained with abundant angular coarse material. The remaining 2012 Project area soils were predominantly single grained with some weak aggregates and angular to rounded coarse material. No massive soils or physical restrictions to root penetration (apart from coarse materials / competent rock) were identified.

### 3.2.4 Structural stability

The structural stability of a soil and its susceptibility to structural decline is complex and depends on the net effect of a number of properties, including the amount and type of clay present, organic matter content, soil chemistry and the nature of disturbance. Soil aggregates that slake and disperse indicate a weak soil structure that is easily degraded. These soils should be seen as potentially problematic when used for the reconstruction of soil profiles for rehabilitation, particularly if left exposed at the surface.

The Emerson Aggregate Test (McKenzie *et al.* 2002) identifies the potential slaking and dispersive properties of soil aggregates. The dispersion test identifies the properties of the soil materials under a worst case scenario, where severe stress is applied to the soil material. Generally, samples allocated into Emerson Classes 1 and 2 are those most likely to exhibit clay dispersion and therefore be the most problematic.

The structural stability of the soils from the Project area was variable, with classifications including Emerson Classes 2, 3a, 3b, 4, 5, 6 and 8 (**Table 5**). Clay dispersion within the soil, indicated by Emerson Class 2 and to a lesser degree Emerson Class 3a and 3b, suggests that those soils are potentially prone to structural decline as a result of clay dispersion and may form a surface seal (hard-set) or be considered as erodible if used as a surface rehabilitation material on constructed slopes. Dispersive soils are also more prone to tunnelling and erosion in areas where surface water pools and the underlying soils remain saturated.

These results should, however, be viewed in conjunction with the particle size distribution, percentage coarse fragments, sodicity, hydraulic conductivity and hardsetting results to obtain a full indication of the likely erodibility and suitability for use as a rehabilitation resource, particularly on constructed slopes. Taking the amount of clay and coarse materials into consideration, the majority of the 2011 and 2012 Project area soils are considered ‘moderately stable’ to ‘stable’, from an erodibility perspective.

**Table 5: Summary of slaking/dispersion properties (Emerson Test) results for the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites, indicating structural stability. Emerson Test classes are included in Appendix B**

| Description | Site | Depth (cm) | Emerson class (24 hour) | Description |
|---|---|---|---|---|
| Project area soil 2011 | Site A1 | 0-5 | 3b | Slaked, remoulded soil dispersed partially |
| | | 10-20 | 3b | Slaked, remoulded soil dispersed partially |
| | | 40-50 | 3b | Slaked, remoulded soil dispersed partially |
| | Site A2 | 0-5 | 5 | Slaked; 1:5 suspension remains dispersed |
| | | 10-20 | 6 | Slaked; 1:5 suspension remains flocculated |
| | | 40-50 | 6 | Slaked; 1:5 suspension remains flocculated |
| | Site A3 | 0-5 | 2 | Slaked, dispersed partially |
| | | 10-20 | 2 | Slaked, dispersed partially |
| | | 40-50 | 2 | Slaked, dispersed partially |
| | Site A4 | 0-5 | 2 | Slaked, dispersed partially |
| | | 10-20 | 6 | Slaked; 1:5 suspension remains flocculated |
| | | 40-50 | 6 | Slaked; 1:5 suspension remains flocculated |
| | Site A5 | 0-5 | 3b | Slaked, remoulded soil dispersed partially |
| | | 10-20 | 5 | Slaked; 1:5 suspension remains dispersed |
| | Site A6 | 0-5 | 5 | Slaked; 1:5 suspension remains dispersed |
| | | 10-20 | 5 | Slaked; 1:5 suspension remains dispersed |
| Project area soil 2012 | Site 1 | 0-20 | 8 | Not slaked; not swollen |
| | | 40-60 | 4 | Slaked; not dispersed |
| | Site 2 | 0-20 | 3b | Slaked, remoulded soil dispersed partially |
| | Site 3 | 0-20 | 8 | Not slaked; not swollen |
| | | 40-60 | 2 | Slaked, dispersed partially |
| | Site 4 | 0-20 | 3a | Slaked, remoulded soil dispersed completely |
| | Site 5 | 0-20 | 5 | Slaked; 1:5 suspension remains dispersed |
| | | 40-60 | 4 | Slaked; not dispersed |
| | | 100-120 | 5 | Slaked; 1:5 suspension remains dispersed |
| | Site 6 | 0-20 | 3b | Slaked, remoulded soil dispersed partially |
| | | 40-60 | 3b | Slaked, remoulded soil dispersed partially |
| TSF Area B footprint soil 2012 | SS07 | 0-5 | 3b | Slaked, remoulded soil dispersed partially |
| | SS08 | 0-5 | 3a | Slaked, remoulded soil dispersed completely |
| TSF Area A footprint soil 2012 | SS09 | 0-5 | 2 | Slaked, dispersed partially |
| | SS10 | 0-5 | 2 | Slaked, dispersed partially |
| | SS11 | 0-5 | 3a | Slaked, remoulded soil dispersed completely |

### 3.2.5 Soil strength

A modified Modulus of Rupture (MOR) test was conducted on the soil fraction (<2 mm) of all 2011 and 2012 Project area soil samples collected. This test is a measure of soil strength and identifies the tendency of a soil to hard-set as a direct result of soil slaking and dispersion. A modulus of rupture of over 60 kPa has been described as the critical value for distinguishing potentially problematic soils in agricultural scenarios (Cochrane and Aylmore 1997). Restricted root penetration into the soil matrix is a likely consequence of a high modulus of rupture. In reconstructed soil profiles, materials normally deep within the profile that may have a high MOR can often be re-deposited closer to the surface, leading to germination / emergence and root penetration problems.

As this test is conducted on reconstructed soil blocks composed of the <2 mm soil fraction, it does not take into account the effect of gravel content or soil structure on soil strength, nor any degree of compaction that may be present in the field. It does, however, provide insight into the potential for layers to hard-set and compact with repeated wetting and drying cycles, and the ability of roots to fracture the soil and penetrate crack faces.

The soil sized fraction (<2 mm) of the majority of the 201 and 2012 Project area soils sampled exhibited soil strength values above 60 kPa (**Figure 12**) and are therefore considered to be prone to hardsetting. This may have some negative implications for the establishment of vegetation in rehabilitated soils. The majority of the soils however have greater than 50% coarse material content which, to a degree, is likely to counteract the negative influence of the potentially hardsetting soil fraction. Nevertheless, it is recommended that soil stripping operations and associated earthworks are not conducted when the soils are wet, as this can exacerbate the decline in soil structure and potential hardsetting of the soil materials.

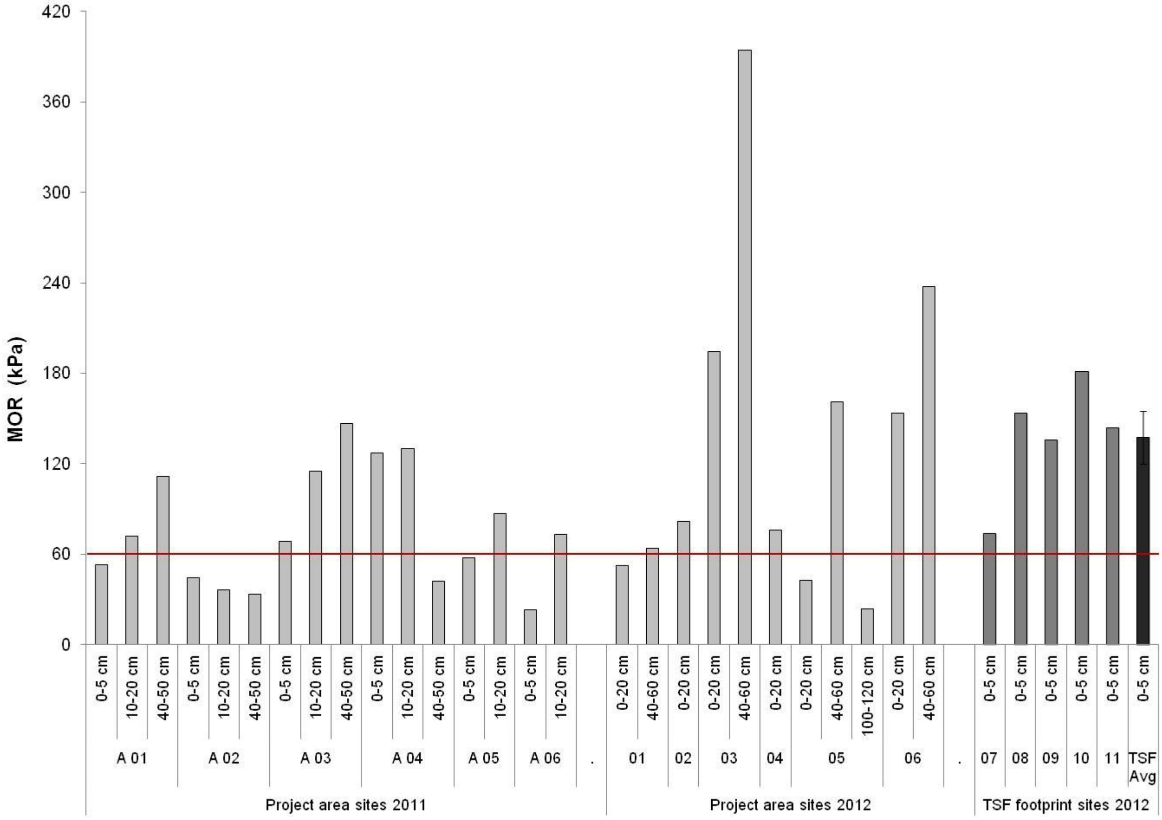


**Figure 12: Individual MOR (kPa) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites. Red line indicates potential restrictions to plant and root development (Cochrane and Aylmore 1997) (error bar represents standard error)**

3.2.6 Saturated hydraulic conductivity ($K_{sat}$)

Hydraulic conductivity ($K_{sat}$) refers to the permeability of soil, or the ability of water to infiltrate and drain through the soil matrix, and is dependent on soil properties such as texture and structure (Hunt and Gilkes 1992; Hazelton and Murphy 2007; Moore 1998). Freely draining soils with high $K_{sat}$ values will generally be less susceptible to surface runoff and erosion. Slow draining soils with low $K_{sat}$ values, are more likely to experience waterlogging, increased surface runoff and erosion.

Saturated hydraulic conductivity refers to the permeability of soil, or the ability of water to infiltrate and drain through the soil matrix, and is dependent on soil properties such as texture and structure (Hunt and Gilkes 1992; Hazelton and Murphy 2007; Moore 1998).

Drainage classes were determined for selected 2011 and all 2012 Project area samples according to their $K_{sat}$ value (Hunt and Gilkes 1992) (**Figure 13**, **Figure 14**, **Table 6**). Soil from Site 3 (40 to 60 cm) was the only sample to exhibit a "slow" drainage class ($K_{sat}$ of 1.49 mm/hr). This soil was a light clay with the lowest coarse material percentage (28%) and a tendency to slake, disperse and hardset. The drainage classes of all other samples ranged from 'moderately slow' to 'rapid', with $K_{sat}$ values ranging from 10.4 to 156.2 mm/hr (**Table 6**).

Repeated $K_{sat}$ analyses were undertaken after a second and third wetting and drying cycle for each 2012 soil sample (**Figure 14**) to identify the influence of settling / consolidation of the soils on the hydraulic conductivity. Results indicate that while there were some fluctuations in $K_{sat}$ values between wetting / drying cycles, the majority of the soils remained within the same drainage class. This suggests that, from a $K_{sat}$ perspective, the soils will retain a relatively constant ability to accept rainfall over wetting and drying cycles.

The soils with the lower $K_{sat}$ values may be problematic from an erodibility perspective if placed on the surface of rehabilitated slopes due to their low saturated hydraulic conductivity and resulting low potential to accept rainfall. However, with the majority of soils classed as having a 'moderate' and 'moderately rapid' drainage class, this indicates a moderate potential for the soils to accept and transmit water.

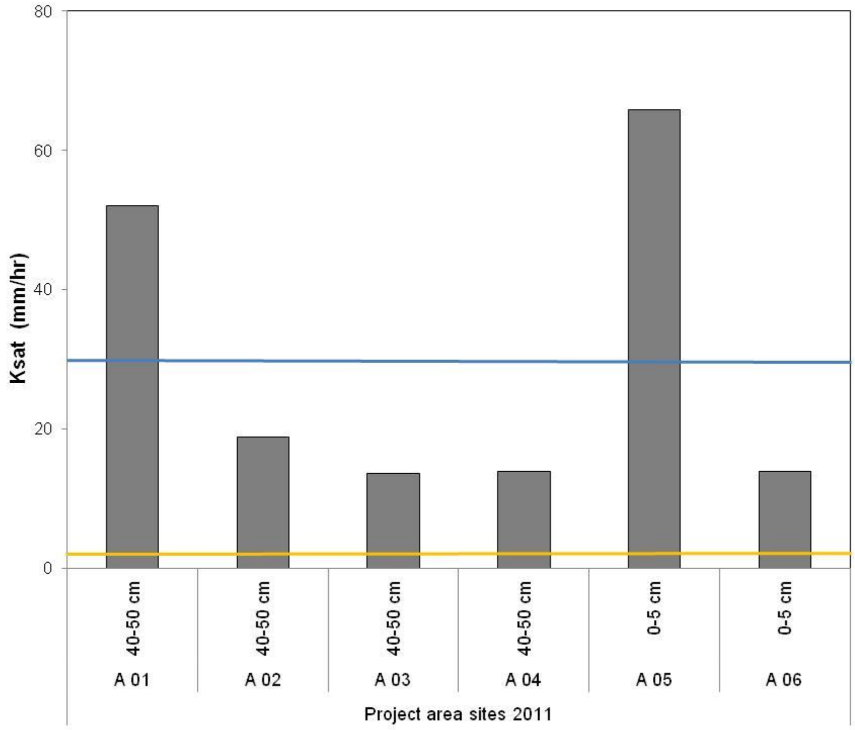


**Figure 13: Individual $K_{sat}$ (mm/hr) values for selected soil samples from the Sulphur Springs Copper Zinc Project area 2011 sites. Horizontal lines indicate average drainage class categories – slow, and moderate (Hunt and Gilkes 1992)**

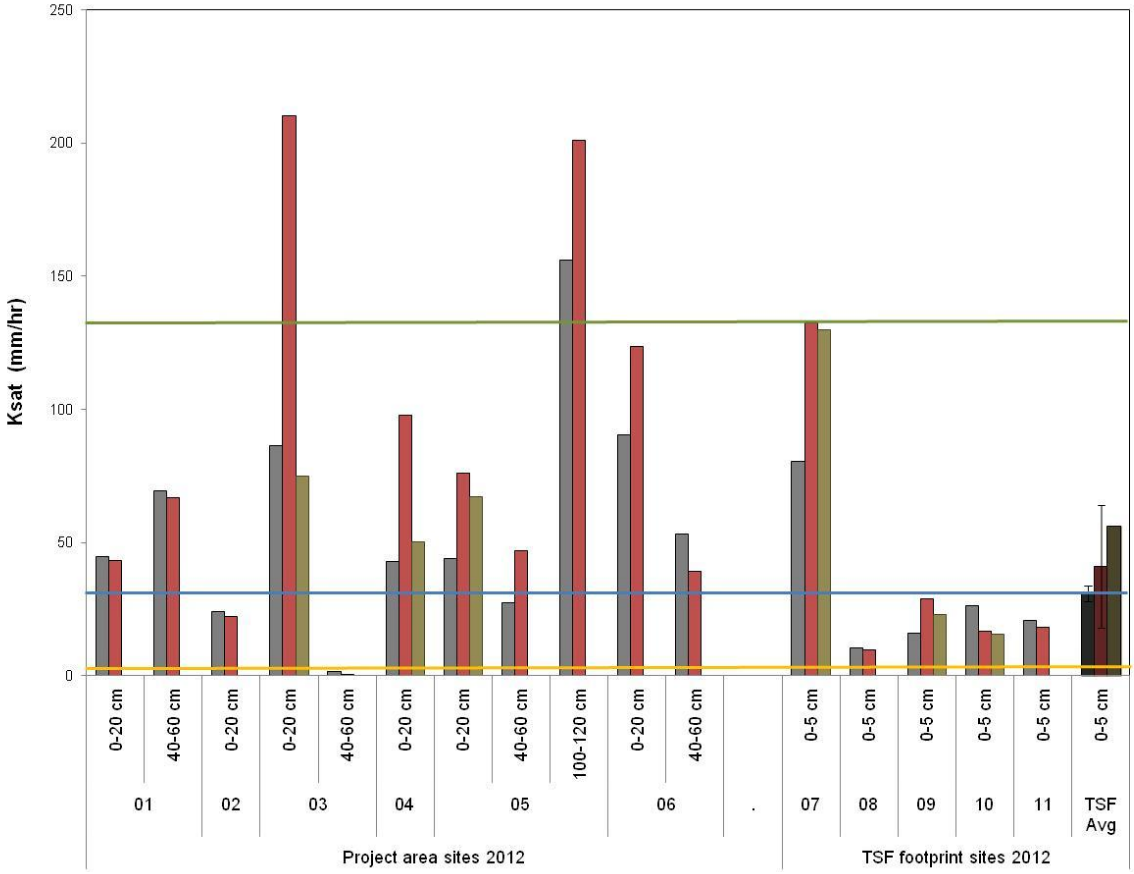


**Figure 14: Individual $K_{sat}$ (mm/hr) values for two and three wetting / drying cycles for the Sulphur Springs Copper Zinc Project area 2012 sites. Horizontal lines indicate average drainage class categories – slow, moderate and rapid (Hunt and Gilkes 1992) (error bar represents standard error)**

**Table 6: Initial saturated hydraulic conductivity (Ksat) values, soil texture, coarse fragment content and drainage class for selected Sulphur Springs Copper Zinc Project area, 2011 and 2012 soil samples**

| Description | Site | Depth (cm) | Soil texture – PSD (hand texture) | Coarse fragments (%) | Initial $k_{sat}$ (mm/hr) | Initial drainage class |
|---|---|---|---|---|---|---|
| Project area soil 2011 | A1 | 40-50 | (Clayey sand) | 75 | 52.01 | Moderate |
| | A2 | 40-50 | (Clayey sand) | 71 | 18.8 | Moderately slow |
| | A3 | 40-50 | Sandy clay loam | 71 | 13.62 | Moderately slow |
| | A4 | 40-50 | (Sandy Loam) | 43 | 13.93 | Moderately slow |
| | A5 | 0-5 | (Sandy loam) | 65 | 65.77 | Moderately rapid |
| | A6 | 0-5 | (Loam) | 49 | 13.95 | Moderately slow |
| | A6 | 10-20 | (Sandy clay loam) | 69 | 44.71 | Moderate |
| Project area soil 2012 | SS01 | 0-20 | Sandy loam | 60 | 69.58 | Moderately rapid |
| | SS01 | 40-60 | Loamy sand | 56 | 23.90 | Moderate |
| | SS02 | 0-20 | Sandy clay | 76 | 86.26 | Moderately rapid |
| | SS03 | 0-20 | Sandy clay loam | 73 | 1.49 | Slow |
| | SS03 | 40-60 | Sandy clay loam | 28 | 42.71 | Moderate |
| | SS04 | 0-20 | Clay loam | 57 | 44.10 | Moderate |
| | SS05 | 0-20 | Silty loam | 34 | 27.28 | Moderate |
| | SS05 | 40-60 | Sandy clay | 51 | 156.21 | Rapid |
| | SS05 | 100-120 | Sandy loam | 68 | 90.61 | Moderately rapid |
| | SS06 | 0-20 | Sandy clay | 74 | 53.14 | Moderate |
| | SS06 | 40-60 | Sandy loam | 63 | 80.43 | Moderately rapid |
| TSF Area B footprint soil 2012 | SS07 | 0-5 | Sandy loam | 61 | 10.39 | Moderately slow |
| | SS08 | 0-5 | Silty loam | 80 | 15.90 | Moderately slow |
| TSF Area A footprint soil 2012 | SS09 | 0-5 | Sandy loam | 71 | 26.37 | Moderate |
| | SS10 | 0-5 | Loamy sand | 68 | 20.60 | Moderate |
| | SS011 | 0-5 | Sandy clay loam | 68 | 44.71 | Moderate |

### 3.2.7 Soil water retention

The water retention properties of the soils within the Project area are an important factor in determining the amount of water that the soils are able to store, and the amount of water available for plant growth when soil materials are re-deposited and rehabilitated. In low-nutrient environments, such as that of the Project area, the amount of water available to plants is often the most limiting factor to vegetation establishment and growth. The water retention or water holding capacity of a soil is influenced by a number of factors, with the particle size (and pore space) distribution, soil structure and organic matter content being the most influential.

All 2012 soil samples from the Project area were selected for analysis of water retention properties on the <2 mm fraction. The water holding capacity of the soil samples was relatively low (**Figure 16**), but typical of analogue soils with the range of soil textures exhibited. This observation is based on the results from other analyses conducted by Outback Ecology of surface soils from similar landforms in the Pilbara region. The water retention curves were relatively similar (**Figure 15**), reflecting the relative similarity in soil textures present (**Figure 16**). As the water pressure increases the amount of water that is held within the pores of the soil materials is reduced (**Figure 16**). The soil water (% volume) at 10 kPa is considered to be the field capacity of the soil (upper storage limit) and 1500 kPa is considered to be the wilting point (lower storage limit) of the soil. Field capacity is the percentage of water remaining in a soil two or three days after it has been saturated and free drainage has practically ceased. Wilting point is the percentage of water in the soil at which plants wilt and fail to recover.

The upper storage limit of the samples (<2 mm fraction) ranged from 25.7% to 47.3% (volumetric) (**Table 7**). This means that when the soil samples are at field capacity, 25.7% to 47.3% of the volume is comprised of water. The lower storage limit of the surface soils ranged from 13.1% to 26.8% (volumetric). This means that when the soil samples are at wilting point, 13.1% to 26.8% of the volume is comprised of water. The plant-available water (PAW), which is the upper storage limit minus lower storage limit of the soil fraction (<2 mm), ranged from 12.6% to 29.5% (volumetric).

Taking the percentage of coarse material into consideration, the upper storage limit of both the soil and coarse fractions combined (the ‘total’ material) is substantially reduced, ranging from 6.1 to 33.8% (volumetric). The PAW of the total material ranged from 3.0% to 14.7% (volumetric) (**Table 7**). These are relatively low PAW values, but are typical of weathered surface soils in the region, particularly those with high gravel / coarse material contents.

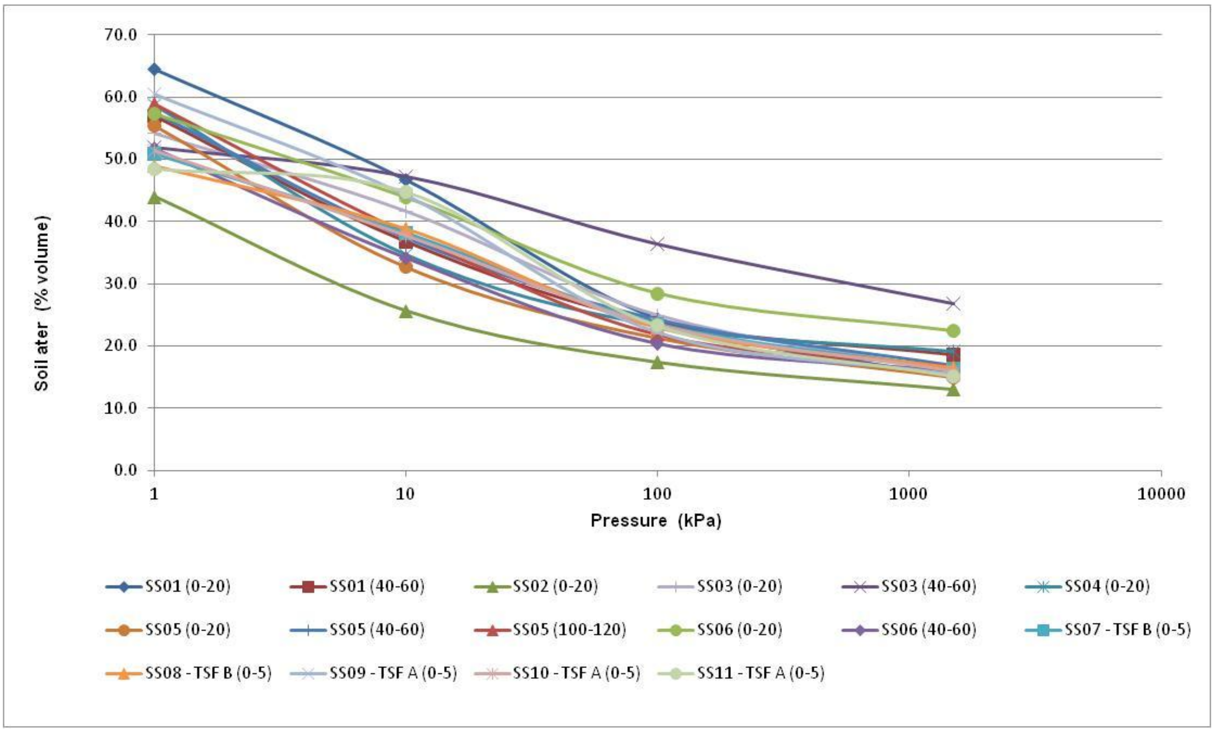


**Figure 15: Water retention curves for selected soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites**

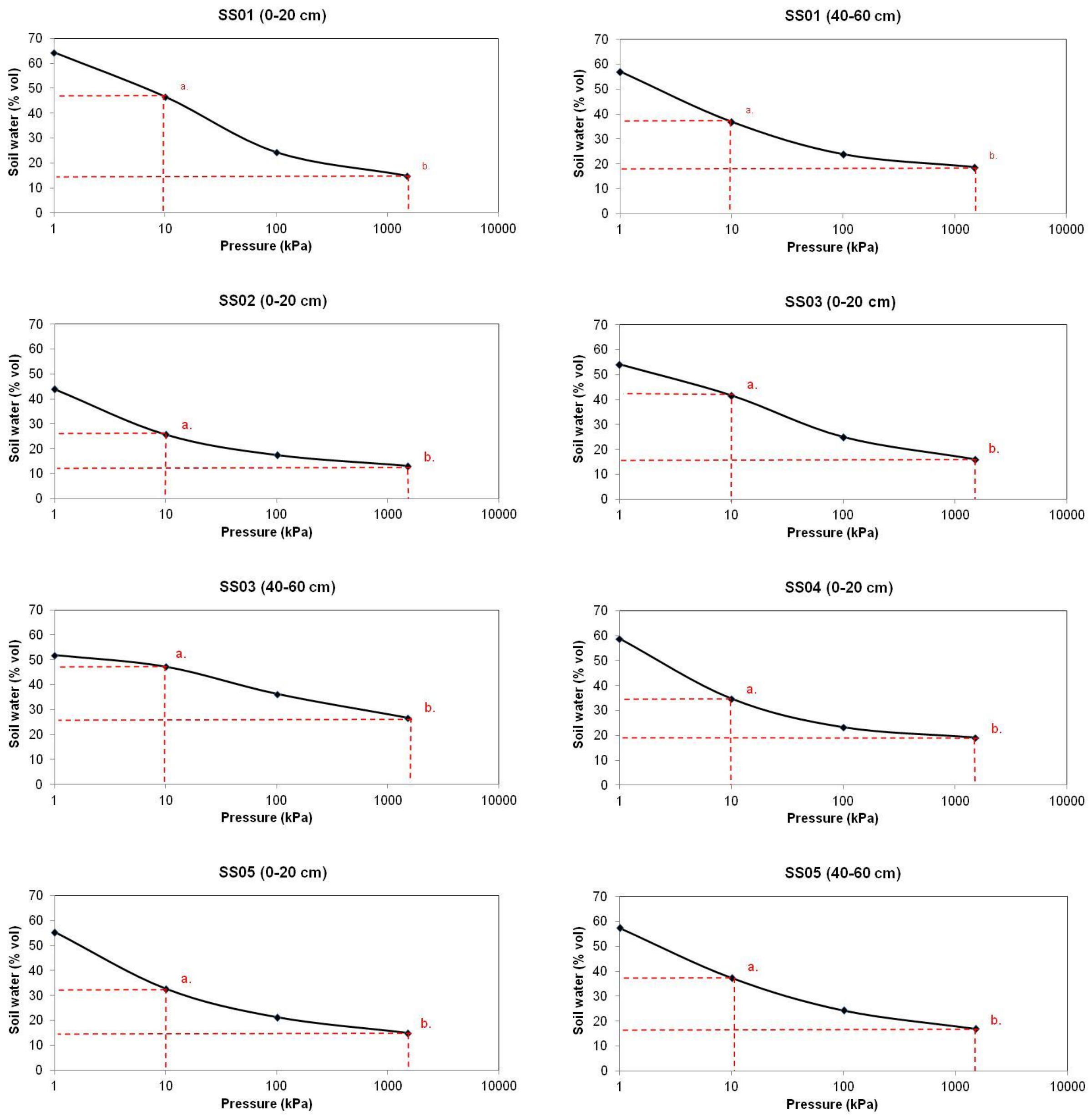


**Figure 16: Water retention curves for individual soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (Water content at point a. is the upper storage limit and point b. is the lower storage limit. The difference in water content between a. and b. is the PAW)**

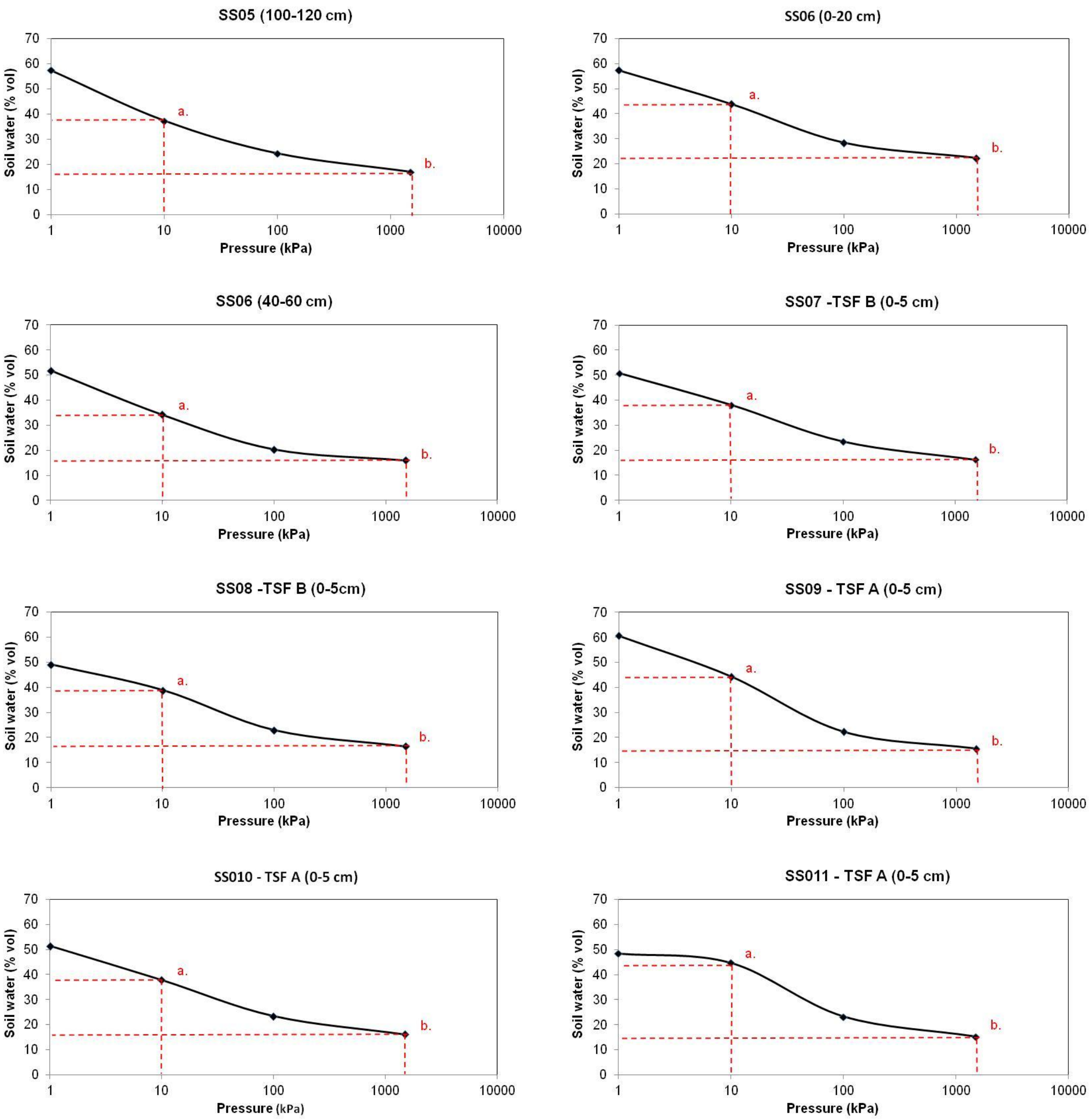


**Figure 17: continued. Water retention curves for individual selected soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (Water content at point a. is the upper storage limit and point b. is the lower storage limit. The difference in water content between a. and b. is the PAW)**

**Table 7: Water retention and availability characteristics for soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites**

| | | | <2 mm fraction | | | Total material [2] | |
|---|---|---|---|---|---|---|---|
| **Description** | **Site** | **Depth interval (m)** | **Upper storage limit[1] (% volume)** | **Lower storage limit[1] (% volume)** | **Plant available water (PAW) (% volume)** | **Upper storage limit (% vol)** | **Plant available water (PAW) (% vol)** |
| Project area soil 2012 | SS01 | 0-20 | 46.7 | 15.0 | 31.7 | 18.7 | 12.7 |
| | SS01 | 40-60 | 36.8 | 18.6 | 18.2 | 16.2 | 8.0 |
| | SS02 | 0-20 | 25.7 | 13.1 | 12.6 | 6.1 | 3.0 |
| | SS03 | 0-20 | 41.7 | 16.0 | 25.6 | 11.2 | 6.9 |
| | SS03 | 40-60 | 47.3 | 26.8 | 20.5 | 33.8 | 14.7 |
| | SS04 | 0-20 | 34.7 | 19.1 | 15.6 | 15.0 | 6.7 |
| | SS05 | 0-20 | 32.7 | 15.0 | 17.7 | 21.5 | 11.6 |
| | SS05 | 40-60 | 37.4 | 16.9 | 20.5 | 18.2 | 9.9 |
| | SS05 | 100-120 | 38.2 | 16.8 | 21.4 | 12.1 | 6.8 |
| | SS06 | 0-20 | 43.9 | 22.4 | 21.5 | 11.5 | 5.6 |
| | SS06 | 40-60 | 34.1 | 16.0 | 18.2 | 12.6 | 6.7 |
| TSF Area B footprint soil 2012 | SS07 | 0-5 | 38.2 | 16.3 | 21.9 | 14.8 | 8.5 |
| | SS08 | 0-5 | 38.9 | 16.5 | 22.4 | 8.0 | 4.6 |
| TSF Area A footprint soil 2012 | SS09 | 0-5 | 44.2 | 15.5 | 28.8 | 13.0 | 8.4 |
| | SS10 | 0-5 | 37.8 | 16.1 | 21.7 | 12.3 | 7.0 |
| | SS11 | 0-5 | 44.7 | 15.2 | 29.5 | 14.3 | 9.4 |

1. Upper storage limit taken at 10 kPa (pF 2), Lower storage limit taken at 1500 kPa (pF 5.5).
2. Taking gravel / coarse material (>2 mm) for each material into account. This assumes water holding capacity of >2 mm coarse fraction is negligible.

## 3.3 Soil physical properties – Kangaroo Caves, Eastern and Airstrip areas - 2013

### 3.3.1 Soil profile morphology

The surface soil profiles investigated within the Kangaroo Caves, Eastern and Air Strip areas exhibited some variation in terms of morphological characteristics. The depth of soil ranged from approximately 30 to 250 cm at the sites.

### 3.3.2 Soil texture

Particle size distribution results indicate that the texture of the soil sized fraction (<2 mm) of the all the Kangaroo Caves, Eastern and Air Strip area soils was 'sandy loam' (**Figure 18**). The clay fraction within the samples was consistent with an average of 13%. The amount of coarse material present (>2 mm) within the soil samples was variable, ranging from 11% to 47% (**Figure 19**). Overall, the Kangaroo Caves, Eastern and Air Strip area soils had comparatively less clay fraction and less coarse material content than the 2011 and 2012 Project area soils.

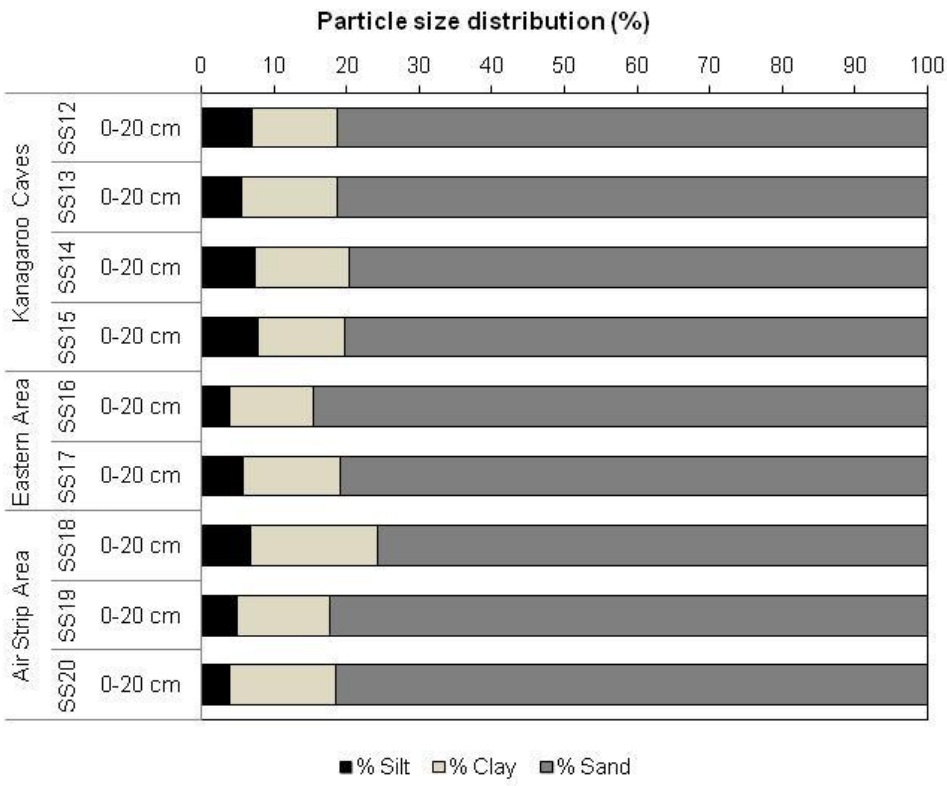


**Figure 18: Individual particle size distribution (%) for soil samples (< 2 mm fraction) from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

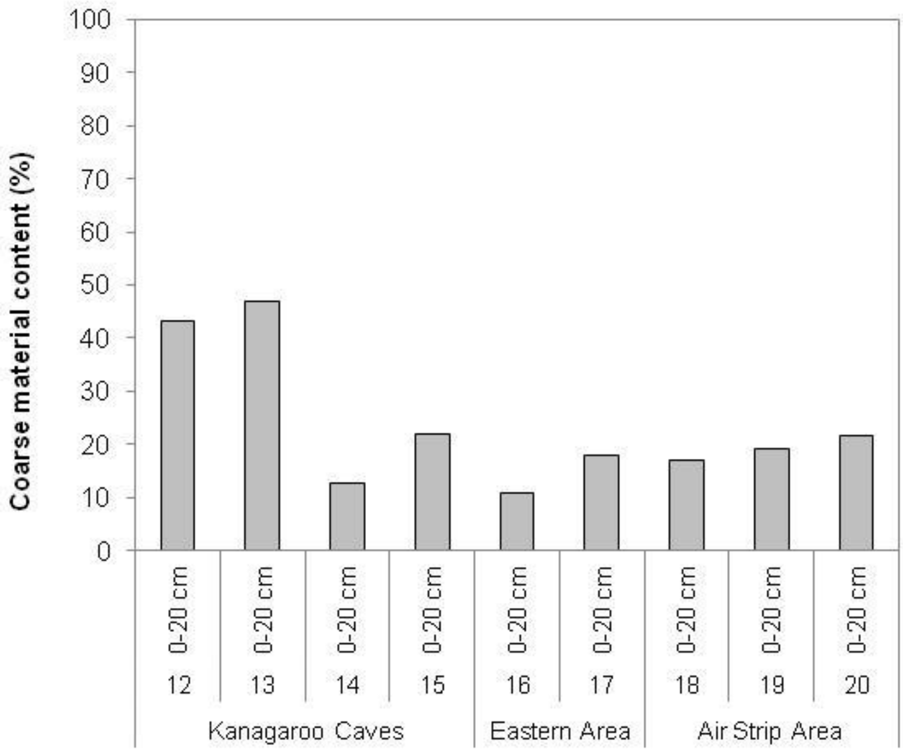


**Figure 19: Individual coarse material content (%) (>2 mm fraction) for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

### 3.3.3 Soil structure

The soils sampled from the Kangaroo Caves and Air Strip areas were predominantly single grained with aggregates and coarse material. No massive soils or physical restrictions to root penetration were identified.

### 3.3.4 Structural stability

The structural stability of the soils from the Kangaroo Caves, Eastern and Air Strip areas was variable, with classifications including Emerson Classes 2, 3b, 4, 5 and 8 (**Table 8**). Clay dispersion within the soil, indicated by Emerson Class 2 and to a lesser degree Emerson Class 3b, suggests that those soils are potentially prone to structural decline as a result of clay dispersion and may form a surface seal (hard-set) or be considered as erodible if used as a surface rehabilitation material on constructed slopes. Dispersive soils are also more prone to tunnelling and erosion in areas where surface water pools and the underlying soils remain saturated.

These results should, however, be viewed in conjunction with the particle size distribution, percentage coarse fragments, sodicity, hydraulic conductivity and hardsetting results to obtain a full indication of the likely erodibility and suitability for use as a rehabilitation resource, particularly on constructed slopes.

The majority of the Kangaroo Caves, Eastern and Air Strip area soils are considered ‘moderately stable’ to ‘stable’, from an erodibility perspective, as were the 2011 and 2012 Project area soils.

**Table 8: Summary of slaking/dispersion properties (Emerson Test) results, indicating structural stability. Emerson Test classes are included in Appendix B**

| Description | Site | Depth (cm) | Emerson class (24 hour) | Description |
|---|---|---|---|---|
| Kanagaroo Caves area soil 2013 | SS12 | 0-20 | 3b | Slaked, remoulded soil dispersed partially |
| | SS13 | 0-20 | 5 | Slaked; 1:5 suspension remains dispersed |
| | SS14 | 0-20 | 5 | Slaked; 1:5 suspension remains dispersed |
| | SS15 | 0-20 | 3b | Slaked, remoulded soil dispersed partially |
| Eastern area soil 2013 | SS16 | 0-20 | 8 | Not slaked; not swollen |
| | SS17 | 0-20 | 4 | Slaked; not dispersed |
| Air Strip area soil 2013 | SS18 | 0-20 | 2 | Slaked, dispersed partially |
| | SS19 | 0-20 | 2 | Slaked, dispersed partially |
| | SS20 | 0-20 | 2 | Slaked, dispersed partially |

### 3.3.5 Soil strength

A modified Modulus of Rupture (MOR) test was conducted on the soil fraction (<2 mm) of all the Kangaroo Caves, Eastern and Air Strip soil samples collected. The majority of the soils exhibited soil strength values below 60 kPa (**Figure 20**) and are therefore considered not prone to hardsetting. This is in contrast to the 2011 and 2012 Project area sites where the majority of the soils were considered to be hardsetting. Nevertheless, it is recommended that soil stripping operations and associated earthworks are not conducted when the soils are wet, as this can exacerbate the decline in soil structure and potential hardsetting of the soil materials.

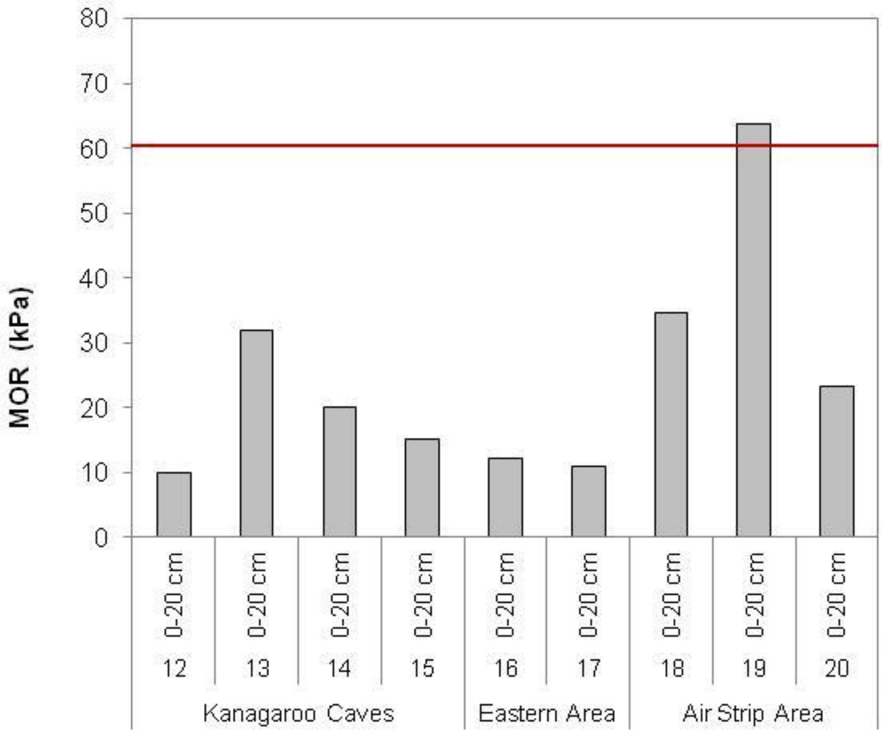


**Figure 20: Individual MOR (kPa) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area. Red line indicates potential restrictions to plant and root development (Cochrane and Aylmore 1997)**

### 3.3.6 Saturated hydraulic conductivity ($K_{sat}$)

Drainage classes were determined for all Kangaroo Caves, Eastern and Air Strip area samples according to their $K_{sat}$ value (Hunt and Gilkes 1992) (**Figure 21**, **Table 9**). The drainage classes of all samples ranged from 'moderately slow' to 'moderately rapid', with $K_{sat}$ values ranging from 10.6 to 122.3 mm/hr (**Table 9**). These drainage classes are similar to those for the 2011 and 2012 Project area surface soils.

The soil with the lowest $K_{sat}$ value (Site 13) may be problematic from an erodibility perspective if placed on the surface of rehabilitated slopes due to the low saturated hydraulic conductivity and resulting low potential to accept rainfall. However, with the majority of soils classed as having a 'moderate' and 'moderately rapid' drainage class, which is similar to the 2011 and 2012 Project area site soils, this indicates a moderate potential for the soils to accept and transmit water.

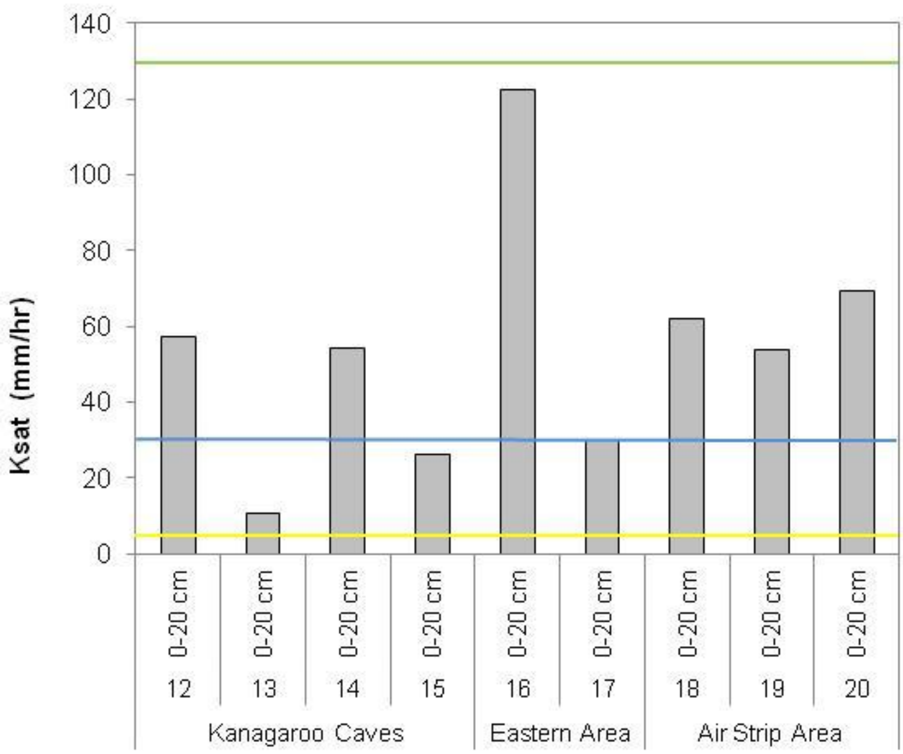


**Figure 21: Individual $K_{sat}$ (mm/hr) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area. Horizontal lines indicate average drainage class categories – slow, moderate and rapid (Hunt and Gilkes 1992)**

**Table 9: Initial saturated hydraulic conductivity (Ksat) values, soil texture, coarse fragment content and drainage class for Kangaroo Caves, Eastern and Air Strip area soil samples of the Sulphur Springs Copper Zinc Project area**

| Description | Site | Depth (cm) | Soil Texture (PSD) | Coarse fragments (%) | $k_{sat}$ (mm/hr) | Initial drainage class |
|---|---|---|---|---|---|---|
| Kanagaroo Caves area soil 2013 | SS12 | 0-20 | Sandy loam | 43 | 57.15 | Moderate |
| | SS13 | 0-20 | Sandy loam | 47 | 10.55 | Moderately slow |
| | SS14 | 0-20 | Sandy loam | 13 | 54.34 | Moderate |
| | SS15 | 0-20 | Sandy loam | 22 | 26.06 | Moderate |
| Eastern area soil 2013 | SS16 | 0-20 | Sandy loam | 11 | 122.26 | Moderately rapid |
| | SS17 | 0-20 | Sandy loam | 18 | 30.05 | Moderate |
| Air Strip area soil 2013 | SS18 | 0-20 | Sandy loam | 17 | 61.87 | Moderate |
| | SS19 | 0-20 | Sandy loam | 19 | 53.92 | Moderate |
| | SS20 | 0-20 | Sandy loam | 22 | 69.27 | Moderately rapid |

### 3.3.7 Soil water retention

A selection of 2013 soil samples from the Project area were analysed for water retention properties on the <2 mm fraction. The water holding capacity of the soil samples was relatively low (**Figure 23**), but typical of analogue soils with the range of soil textures exhibited. This observation is based on the results from other analyses conducted by Outback Ecology of surface soils from similar landforms in the Pilbara region. The water retention curves were relatively similar (**Figure 22**), reflecting the relative similarity in soil textures present (**Figure 23**). As the water pressure increases the amount of water that is held within the pores of the soil materials is reduced (**Figure 23**).

The upper storage limit of the samples (<2 mm fraction) ranged from 23.2% to 35.2% (volumetric) (**Table 10**). This means that when the soil samples are at field capacity, 23.2% to 35.2% of the volume is comprised of water. The lower storage limit of the surface soils ranged from 11.5% to 16.2% (volumetric). This means that when the soil samples are at wilting point, 11.5% to 16.2% of the volume is comprised of water. The plant-available water (PAW), which is the upper storage limit minus the lower storage limit of the soil fraction (<2 mm), ranged from 11.7% to 19.0% (volumetric).

Taking the percentage of coarse material into consideration, the upper storage limit of both the soil and coarse fractions combined (the ‘total’ material) is reduced, ranging from 17.1 to 30.7% (volumetric). The PAW of the total material ranged from 9.2% to 16.6% (volumetric) (**Table 10**). These are low to medium PAW values, but are typical of weathered surface soils in the region, particularly those with low gravel / coarse material contents.

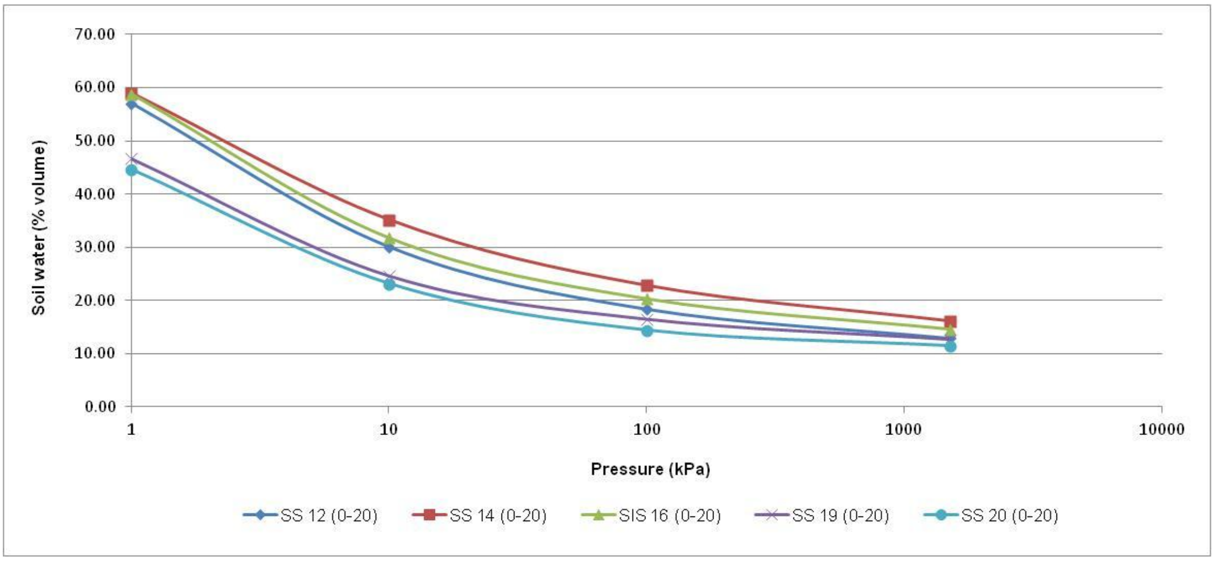


**Figure 22: Water retention curves for selected soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area.**

**(Note: Logarithmic scale)**

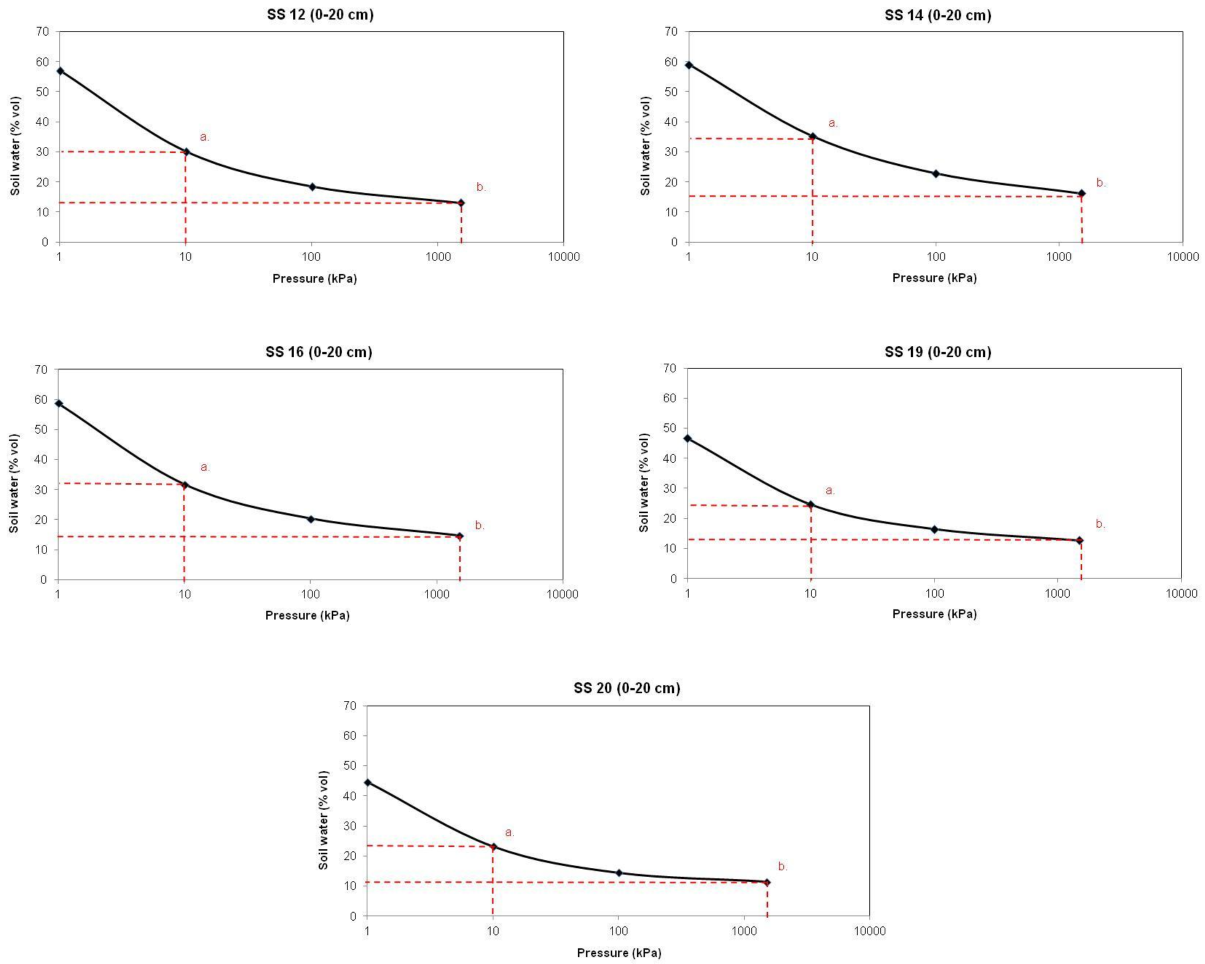


**Figure 23: Water retention curves for individual soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area (Water content at point a. is the upper storage limit and point b. is the lower storage limit. The difference in water content between a. and b. is the PAW)**

**(Note: Logarithmic scale)**

**Table 10: Water retention and availability characteristics for soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project**

| Description | Site | Depth interval (m) | <2 mm fraction | | | Total material [2] | |
|---|---|---|---|---|---|---|---|
| | | | Upper storage limit[1] (% volume) | Lower storage limit[1] (% volume) | Plant available water (PAW) (% volume) | Upper storage limit (% vol) | Plant available water (PAW) (% vol) |
| Kanagaroo Caves area soil 2013 | SS12 | 0-20 | 30.1 | 13.0 | 17.2 | 17.1 | 9.7 |
| | SS14 | 0-20 | 35.2 | 16.2 | 19.0 | 30.7 | 16.6 |
| Eastern area soil 2013 | SS16 | 0-20 | 31.8 | 14.7 | 17.1 | 28.3 | 15.2 |
| Air Strip area soil 2013 | SS19 | 0-20 | 24.7 | 12.7 | 12.0 | 19.9 | 9.7 |
| | SS20 | 0-20 | 23.2 | 11.5 | 11.7 | 18.2 | 9.2 |

1. Upper storage limit taken at 10 kPa (pF 2), Lower storage limit taken at 1500 kPa (pF 5.5).
2. Taking gravel / coarse material (>2 mm) for each material into account. This assumes water holding capacity of >2 mm coarse fraction is negligible.

## 3.4 Soil chemical properties – Project area sites – 2011 and 2012

### 3.4.1 Soil pH

The soil pH gives a measure of the soil acidity or alkalinity, with ratings determined by pH range and analysis method (Van Gool *et al*. 2005). The ideal pH range for plant growth of most agricultural species is considered to be between 5.0 and 7.5 (Moore 1998). Outside this range, the plant-availability of some nutrients is affected, while various metal toxicities (e.g. Al and Mn) can become limiting at low pH. For native species, which are known to be tolerant of wider ranges in soil pH, preferred pH ranges are best inferred from the soil in which they are observed to occur.

Soil pH measured in 0.01 M calcium chloride ($CaCl_2$) is considered a more accurate measurement of hydrogen ion concentration ($[H^+]$), closer to that of the natural soil solution which is taken up by plants (Hunt and Gilkes 1992). As a result, soil pH measured in $CaCl_2$ is lower than pH measured in water, however both measurements are taken for a complete assessment.

There was a range of soil pH values recorded for the soils sampled from the Project area. Soil pH ($CaCl_2$) ranged from 'strongly acidic' (pH 4.5) to 'strongly alkaline' (pH 8.3) (**Figure 24**). Soil pH ($H_2O$) also ranged from 'strongly acidic' (pH 5.4) to 'strongly alkaline' (pH 9.2) (**Figure 25**). The 2011 Project area samples, overall, had a lower soil pH than the TSF footprint and 2012 Project area samples.

The majority of the soil pH values were within the optimum range for plant growth of Pilbara plant species, with soil pH unlikely to be a limiting factor to successful vegetation growth of rehabilitated areas.

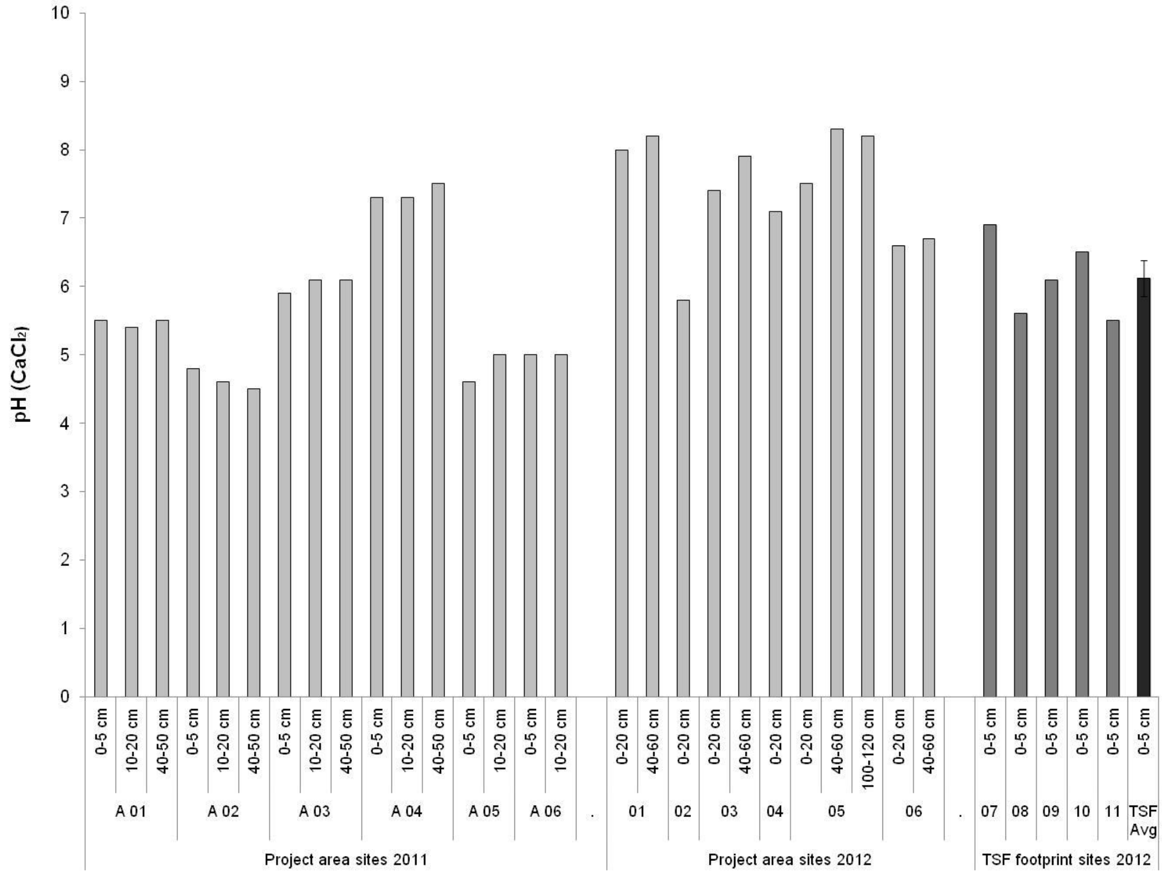


**Figure 24: Individual soil pH ($CaCl_2$) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)**

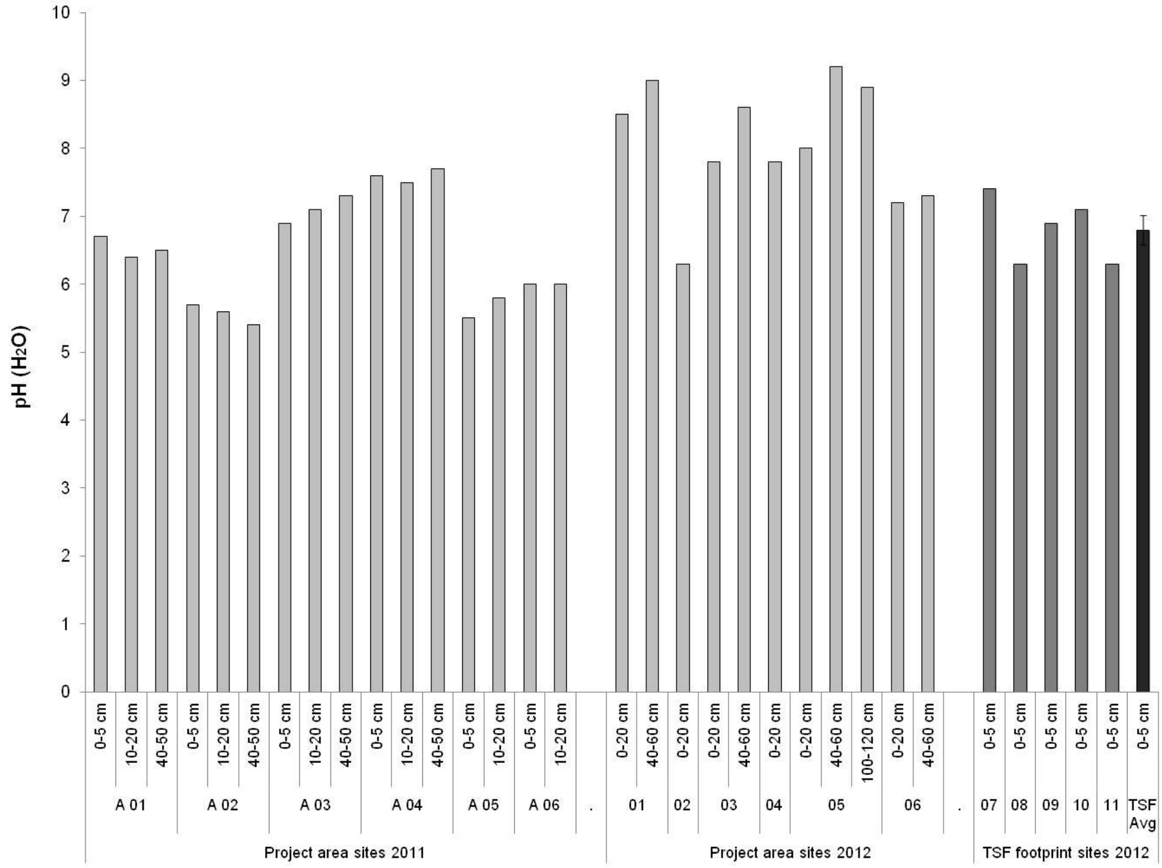


**Figure 25: Individual soil pH ($H_2O$) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)**

### 3.4.2 Electrical conductivity

Electrical conductivity (EC) is a measurement of the soluble salts in soils or water. The amount of salt in the soil determines its ability to conduct an electric current. High levels of soluble salts lower the osmotic potential of the soil water, making it more difficult for roots to remove water from the soil (Brady and Weil 2002).

The EC values of the soils sampled ranged from 0.018 to 3.930 dS/m (**Figure 26**), with the majority of samples classified as 'non-saline' based on the standard USDA and CSIRO categories (**Appendix B**). Soils from Site A4 and Site 3 (40 to 60 cm) were classified as 'very saline' to 'extremely saline'.

The relatively low EC values, except for Site A4 and Site 3 (40 to 60 cm), indicate that there is a very low risk of salinity related issues occurring if the soils are stripped, stockpiled and used as a surface rehabilitation medium.

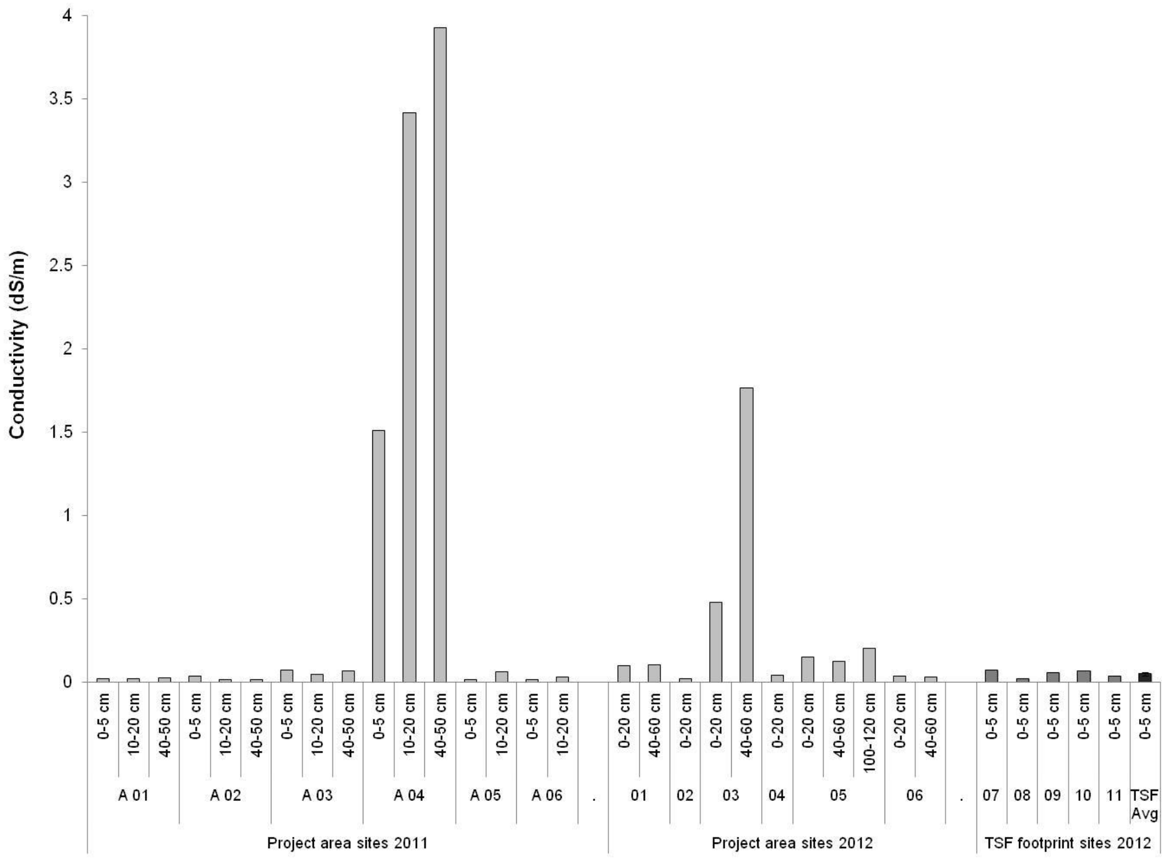


**Figure 26: Individual electrical conductivity (EC 1:5 $H_2O$) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)**

### 3.4.3 Soil organic carbon

The organic matter content of soil is an important factor influencing many physical, chemical and biological soil characteristics. Directly derived from plants and animals, its functions in soil include supporting the micro and macro fauna and flora populations in the soil, increasing the water retention capacity, buffering pH and improving soil structure. The organic matter content of the soils within the study area was determined as a measure of the soil organic carbon percentage (SOC%).

The SOC% within the majority of the Project area soils was low (<1% SOC) (Moore 1998), as is the case in most natural Western Australian arid land soils, with individual values ranging between 0.10% and 1.02% (**Figure 27**). As would be expected, the highest organic carbon values were generally measured in the topsoil (0 to 20 cm) with the TSF footprint soils having the overall highest values.

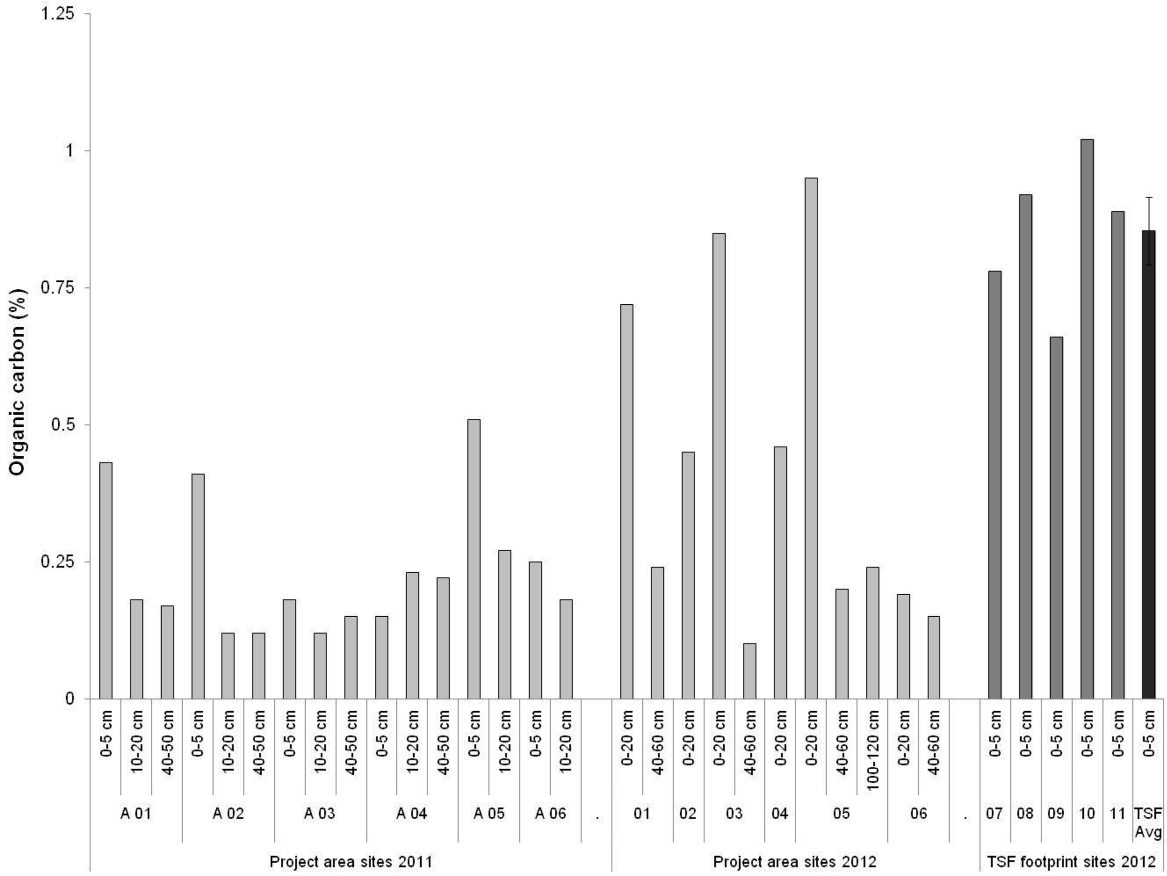


**Figure 27: Individual soil organic carbon (%) values for soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bars represent standard error)**

### 3.4.4 Exchangeable cations and exchangeable sodium percentage (ESP)

Exchangeable cations held on clay surfaces and within organic matter are an important source of soil fertility and can influence the physical properties of soil. Generally, if cations such as $Ca^{2+}$, $Mg^{2+}$ and $K^{+}$ are dominant on the clay exchange surfaces, the soil will typically display increased physical structure and stability, leading to increased aeration, drainage and root growth (Moore 1998). If Na cations ($Na^{+}$) are dominant on exchange surfaces and exceed more than 6% of the total exchangeable cations, then the soil is considered to be *sodic*, which can lead to poor physical properties (i.e. dispersion, hard-setting and erosion in clay-rich soils).

If the ESP exceeds more than 15%, then the soil is considered to be *highly sodic* (Moore 1998). Sodic soils have an increased tendency to disperse upon wetting and are therefore more prone to hardsetting at the soil surface, and erosion when placed on the slopes of constructed landforms.

The majority of soil samples (soil sized fraction) from within the Project area were classified as 'non-sodic' with ESP values less than 6% or exchangeable sodium values below the level of detection (**Table 11**). Site A3 and Site 3 recorded ESP values between 6.57% and 14.08% indicating 'sodic' soils. However, all these samples had low effective cation exchange capacity (eCEC) values (< 3 meq/100g) indicating that the dispersive effect of high sodicity is likely to be minimal. This is evidenced by the relatively low amounts of clay dispersion identified by the Emerson Aggregate Test (**Section 3.2.4**). In summary, the majority of the soils from the Project area are considered unlikely to be problematic from a clay dispersion and derived erodibility perspective. Care should be taken, however, to minimise the handling of the soil materials where possible, particularly when wet.

**Table 11: Individual exchangeable sodium percentage (ESP) (%) and effective cation exchange capacity (eCEC) values for the soil sized fraction (< 2 mm) of the Sulphur Springs Copper Zinc Project area 2011 and 2012 surface soil samples**

| Description | Site | Depth (cm) | ESP (%)[1] | eCEC (meq/100g) |
|---|---|---|---|---|
| Project area soil 2011 | Site A1 | 0-5 | BDL | 3.35 |
| | | 10-20 | BDL | 2.90 |
| | | 40-50 | BDL | 3.57 |
| | Site A2 | 0-5 | BDL | 1.49 |
| | | 10-20 | BDL | 1.58 |
| | | 40-50 | BDL | 1.60 |
| | Site A3 | 0-5 | 8.16 | 1.47 |
| | | 10-20 | 7.04 | 2.13 |
| | | 40-50 | 14.08 | 1.42 |
| | Site A4 | 0-5 | 2.44 | 7.39 |
| | | 10-20 | 3.73 | 9.91 |
| | | 40-50 | 3.50 | 13.13 |
| | Site A5 | 0-5 | BDL | 1.22 |
| | | 10-20 | BDL | 1.70 |
| | Site A6 | 0-5 | BDL | 2.46 |
| | | 10-20 | BDL | 3.23 |
| Project area soil 2012 | Site 1 | 0-20 | BDL | 3.35 |
| | | 40-60 | BDL | 2.90 |
| | Site 2 | 0-20 | BDL | 3.57 |
| | Site 3 | 0-20 | 2.06 | 1.49 |
| | | 40-60 | 6.57 | 1.58 |
| | Site 4 | 0-20 | BDL | 1.60 |
| | Site 5 | 0-20 | BDL | 1.47 |
| | | 40-60 | BDL | 2.13 |
| | | 100-120 | 2.43 | 1.42 |
| | Site 6 | 0-20 | BDL | 7.39 |
| | | 40-60 | BDL | 9.91 |
| TSF Area B footprint soil 2012 | SS07 | 0-5 | BDL | 13.13 |
| | SS08 | 0-5 | BDL | 1.22 |
| TSF Area A footprint soil 2012 | SS09 | 0-5 | BDL | 1.70 |
| | SS10 | 0-5 | BDL | 2.46 |
| | SS11 | 0-5 | BDL | 3.23 |

1. BDL: Exchangeable sodium below detection limit, assumed non-sodic.

#### 3.4.5 Plant-available soil nutrients

The most important macronutrients for plant growth are nitrogen (N), phosphorus (P), potassium (K), and sulphur (S). These nutrients are largely derived from the soil mineral component and organic matter.

Native plant species have a number of physiological adaptations that enable them to be productive in areas where the supply of macronutrients is limited. There is limited information available which details the specific nutritional requirements for native plant species in the semiarid zone of WA. Therefore, the use of analogue sites is an effective way to baseline the soil nutritional requirements of native plant species within the Project area.

#### *3.4.5.1 Plant-available nitrogen*

A significant proportion of soil nitrogen is held in organic matter and it is not immediately available for plant uptake (Hazelton and Murphy 2007). The nitrogen that is readily available to plants is generally measured as nitrate. Nitrogen is an integral component of many essential plant compounds. It is a major part of all amino acids, which are the building blocks of all proteins, including the enzymes which effectively control all biological processes (Brady and Weil 2002). A good supply of nitrogen stimulates root growth and development, and enhances the uptake of other nutrients (Brady and Weil 2002).

Plant-available nitrogen was typically low, ranging from <1 (below the detectable limit) to 8 mg/kg (**Figure 28**). Site A4 had relatively high plant-available nitrogen values ranging from 29 mg/kg to 57 mg/kg.

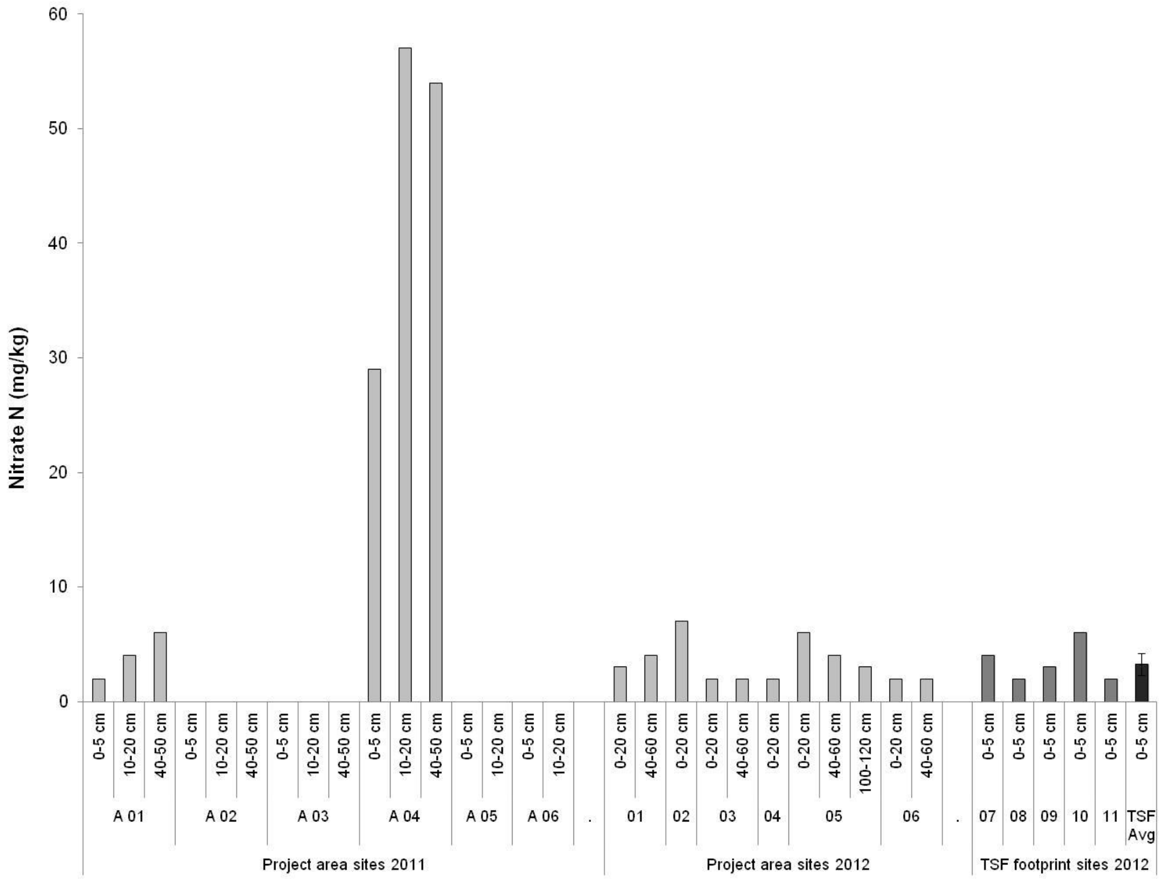


**Figure 28: Individual plant-available nitrogen (nitrate N) (mg/kg) values for soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)**

*3.4.5.2 Plant-available phosphorus*

Phosphorus is essential for the growth of plants and animals as it plays a key role in the formulation of energy producing organic compounds. Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production), and maturation (Brady and Weil 2002).

Plant-available phosphorus for all samples was classed as 'low' (<10 mg/kg) to 'medium' (10 to 30 mg/kg) (Moore 1998) with individual concentrations ranging from <2 (below the detectable limit) to 10 mg/kg (**Figure 29**).

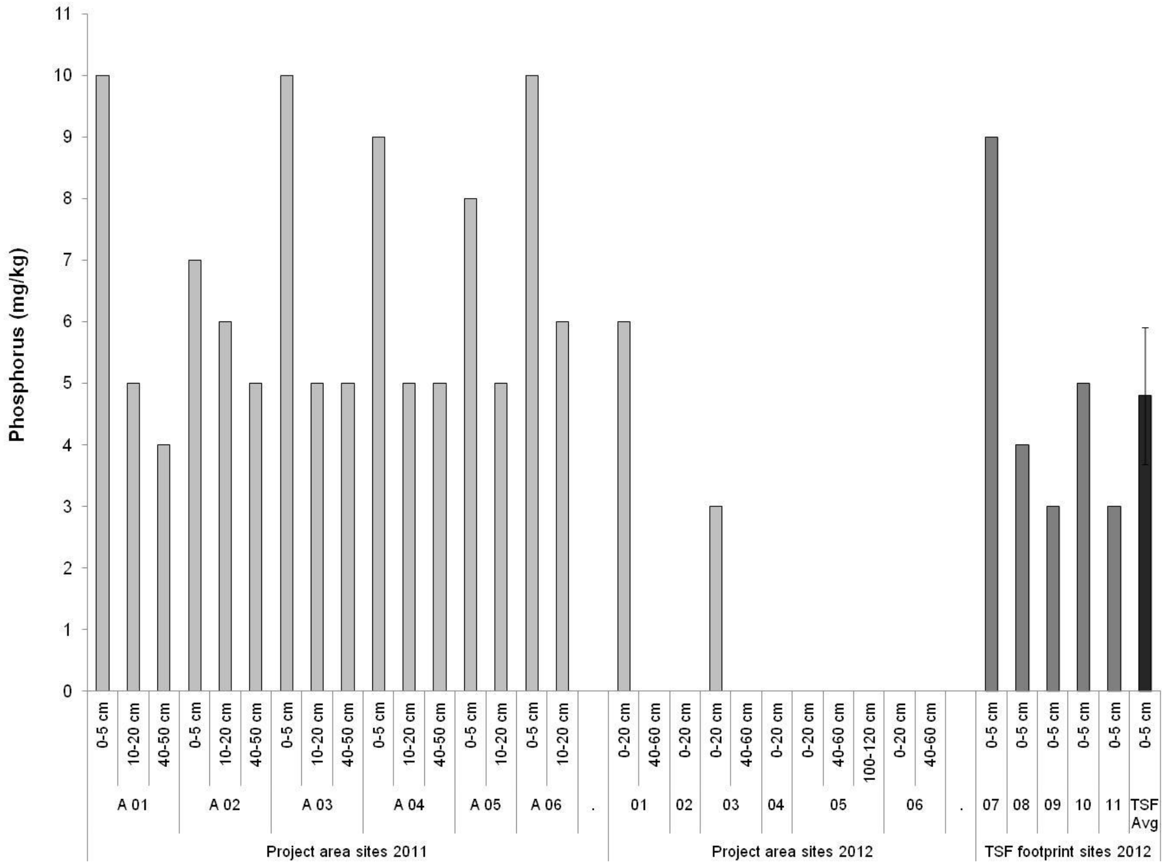


**Figure 29: Individual plant-available phosphorus (P) (mg/kg) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bars represent standard error)**

### *3.4.5.3 Plant-available potassium*

Potassium (K) plays a critical role in a number of plant physiological processes. Adequate amounts of K have been linked to improved drought tolerance, improved winter hardiness, better resistance to certain fungal diseases, and greater tolerance to insect pests. Potassium can also improve the structural stability of plants (Brady and Weil 2002).

Plant-available potassium within all soils sampled was classed as 'low' to 'high' (Moore 1998) ranging from <15 (below the detectable limit) to 404 mg/kg (**Figure 30**).

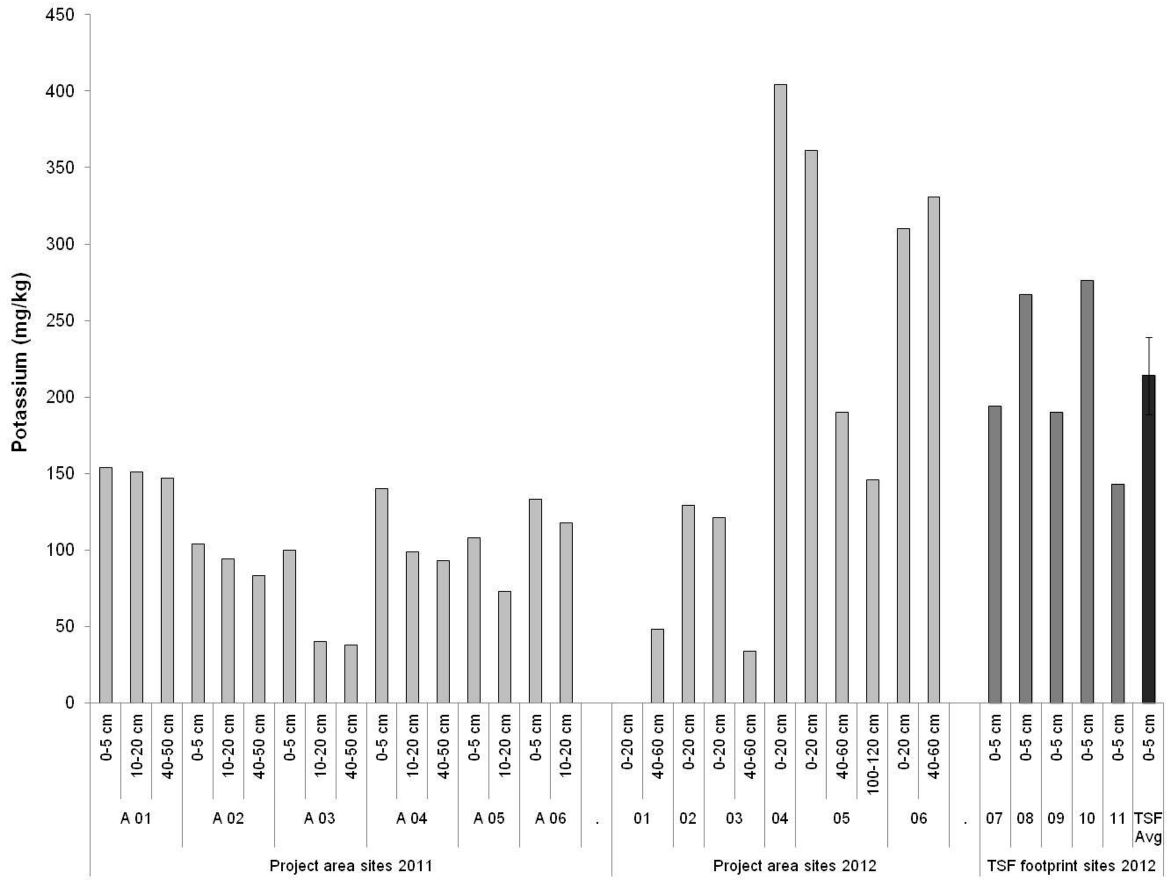


**Figure 30: Individual plant-available potassium (K) (mg/kg) values for soils from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bars represent standard error)**

*3.4.5.4 Plant-available sulphur*

Sulphur is a constituent of many protein enzymes that regulate activities such as photosynthesis and nitrogen fixation (Brady and Weil 2002). Symptoms of sulphur deficiency are similar to those associated with nitrogen deficiency. Plants deficient in sulphur tend to become spindly and develop thin stems and petioles. Plant growth will be slowed, and maturity may be delayed. The plants will also develop a light green or yellow appearance. Sulphur is relatively immobile in the plant, so chlorosis (light-green shading) develops first on the youngest leaves as sulphur supplies are gradually depleted (Brady and Weil 2002).

Plant-available sulphur concentration for the majority of the soils was below 20 mg/kg (**Figure 31**). Relatively high values were recorded (up to 1645.7 mg/kg) at Site A4 and Site 3.

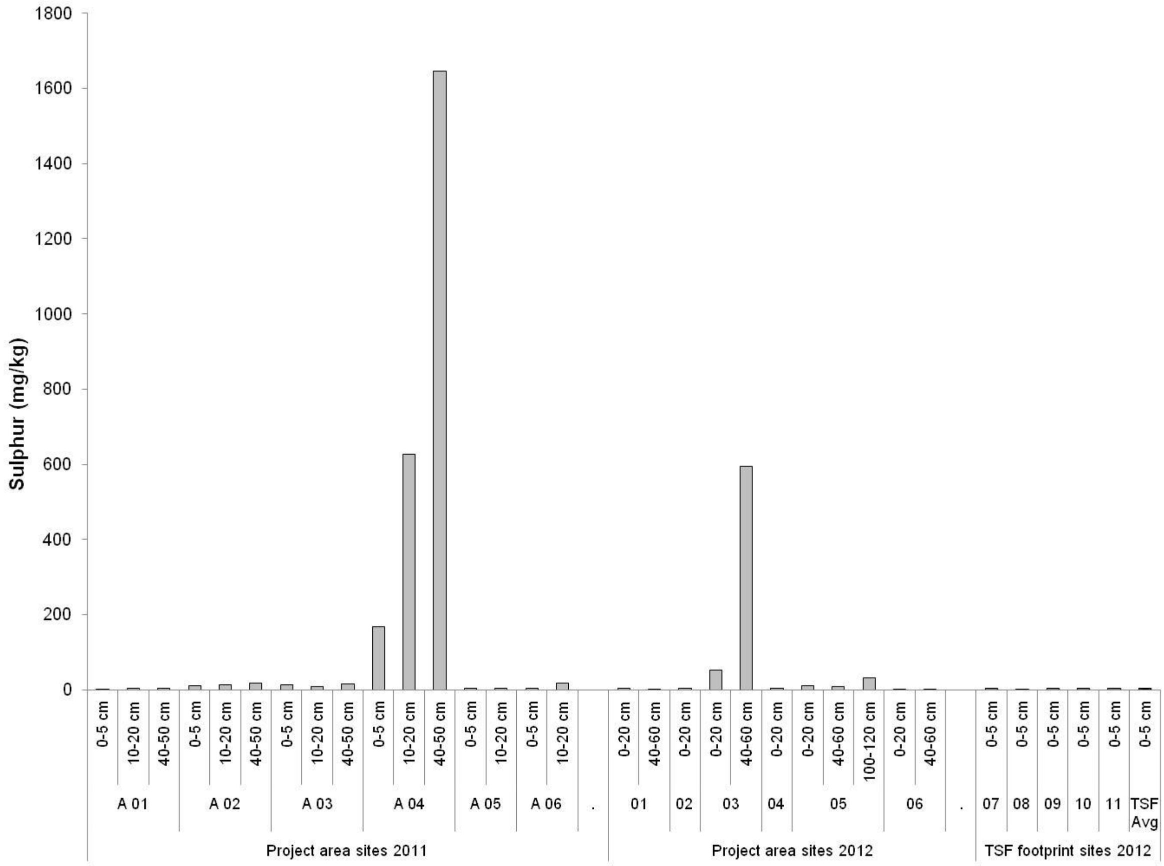


**Figure 31: Individual plant-available sulphur (S) (mg/kg) values for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites (error bar represents standard error)**

### 3.4.6 Total metal concentrations

Measurements of total metal concentrations of the soil samples indicated that variable levels of Cr, Cu, Ni, and Zn were present (**Table 12**). Most materials sampled were below the detectable limit of reporting (LOR) for As and Hg, and often below the LOR for Cd. Concentrations of Cr, Cu, Pb, Ni and Zn were regularly detected at a reportable level (**Table 12**).

All results were compared with 'Ecological Investigation Levels' (EILs) for soils (DEC 2010). The EILs are intended as a guide only, as higher EIL values may be acceptable for some metal concentrations, such as As, Cr, Cu, Ni, Pb and Zn, in areas where soils naturally have high background concentrations of these substances (DEC 2010). The levels of Cu, Ni and Zn were measured above the default EILs for soils (DEC 2010) in some samples from the Project area (**Table 12**).

**Table 12: Individual total metal values (mg/kg) and limits of reporting (LOR) for soil samples from the Sulphur Springs Copper Zinc Project area 2011 and 2012 sites**

| Description | Site | Depth (cm) | Analyte (mg/kg) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Arsenic | Cadmium | Chromium | Copper | Lead | Nickel | Zinc | Mercury |
| Project area soil 2011 | Site A1 | 0-5 | <5 | **3** | **76** | **23** | **7** | **47** | **202** | <0.1 |
| | | 40-50 | <5 | **3** | **93** | **32** | **12** | **73** | **262** | <0.1 |
| | Site A2 | 0-5 | <5 | **2** | **83** | **30** | **22** | **27** | **39** | <0.1 |
| | | 40-50 | <5 | **2** | **73** | **19** | **12** | **20** | **24** | <0.1 |
| | Site A3 | 0-5 | <5 | **2** | **54** | **14** | **6** | **15** | **34** | <0.1 |
| | | 40-50 | <5 | **2** | **56** | **18** | **7** | **31** | **43** | <0.1 |
| | Site A4 | 0-5 | <5 | **2** | **73** | **32** | **8** | **42** | **52** | <0.1 |
| | | 40-50 | <5 | <1 | **39** | **30** | **5** | **40** | **44** | <0.1 |
| | Site A5 | 0-5 | <5 | **1** | **71** | **21** | **23** | **19** | **46** | <0.1 |
| | Site A6 | 0-5 | <5 | **2** | **186** | **32** | **8** | **44** | **58** | <0.1 |
| Project area soil 2012 | Site 1 | 0-20 | <5 | <1 | **72** | **35** | **8** | **66** | **110** | <0.1 |
| | | 40-60 | <5 | **1** | **56** | **24** | **9** | **52** | **110** | <0.1 |
| | Site 2 | 0-20 | <5 | <1 | **36** | **12** | **6** | **11** | **19** | <0.1 |
| | Site 3 | 0-20 | <5 | <1 | **41** | **19** | **10** | **30** | **73** | <0.1 |
| | | 40-60 | <5 | <1 | **15** | **10** | **7** | **16** | **63** | <0.1 |
| | Site 4 | 0-20 | <5 | **2** | **528** | **383** | **18** | **141** | **172** | <0.1 |
| | Site 5 | 0-20 | <5 | **1** | **131** | **119** | **12** | **65** | **260** | <0.1 |
| | | 40-60 | <5 | <1 | **88** | **110** | **7** | **39** | **59** | <0.1 |
| | | 100-120 | <5 | <1 | **76** | **106** | **7** | **33** | **59** | <0.1 |
| | Site 6 | 0-20 | <5 | <1 | **168** | **85** | **15** | **174** | **126** | <0.1 |
| | | 40-60 | <5 | <1 | **245** | **104** | **11** | **240** | **110** | <0.1 |
| TSF Area B footprint soil 2012 | Site 7 | 0-5 | <5 | <1 | **18** | **41** | **5** | **12** | **71** | <0.1 |

| Description | Site | Depth (cm) | Analyte (mg/kg) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Arsenic | Cadmium | Chromium | Copper | Lead | Nickel | Zinc | Mercury |
| | Site 8 | 0-5 | <5 | <1 | **29** | **13** | **5** | **12** | **26** | <0.1 |
| TSF Area A footprint soil 2012 | Site 9 | 0-5 | <5 | <1 | **26** | **16** | **6** | **9** | **18** | <0.1 |
| | Site 10 | 0-5 | <5 | <1 | **17** | **6** | <5 | **7** | **17** | <0.1 |
| | Site 11 | 0-5 | <5 | <1 | **20** | **10** | <5 | **7** | **15** | <0.1 |
| **LOR (mg/kg)** | | | **5** | **1** | **2** | **5** | **5** | **2** | **5** | **0.1** |
| **EIL (mg/kg)** | | | **20** | **3** | **1* / 400^** | **100** | **600** | **60** | **200** | **1** |

Note: Values in bold indicate levels detected above Limits of Reporting (LOR), levels above the Ecological Investigation Levels (EIL) (DEC 2010) are highlighted in orange.

* = EIL for Chromium VI

^ = EIL for Chromium III

## 3.5 Soil chemical properties – Kangaroo Caves and Airstrip areas - 2013

### 3.5.1 Soil pH

There was a range of soil pH values recorded for the soils sampled from the Kangaroo Caves, Eastern and Air Strip area. Soil pH ($CaCl_2$) ranged from 'moderately acidic' (pH 4.8) to 'moderately alkaline' (pH 7.6) (**Figure 32**). Soil pH ($H_2O$) also ranged from 'moderately acidic' (pH 5.8) to 'moderately alkaline' (pH 8.4) (**Figure 33**). The 2011 and 2012 Project area samples, overall, had a greater range of soil pH values than the Kangaroo Caves, Eastern and Air Strip area samples.

The majority of the soil pH values were within the optimum range for plant growth of Pilbara plant species, with soil pH unlikely to be a limiting factor to successful vegetation growth of rehabilitated areas.

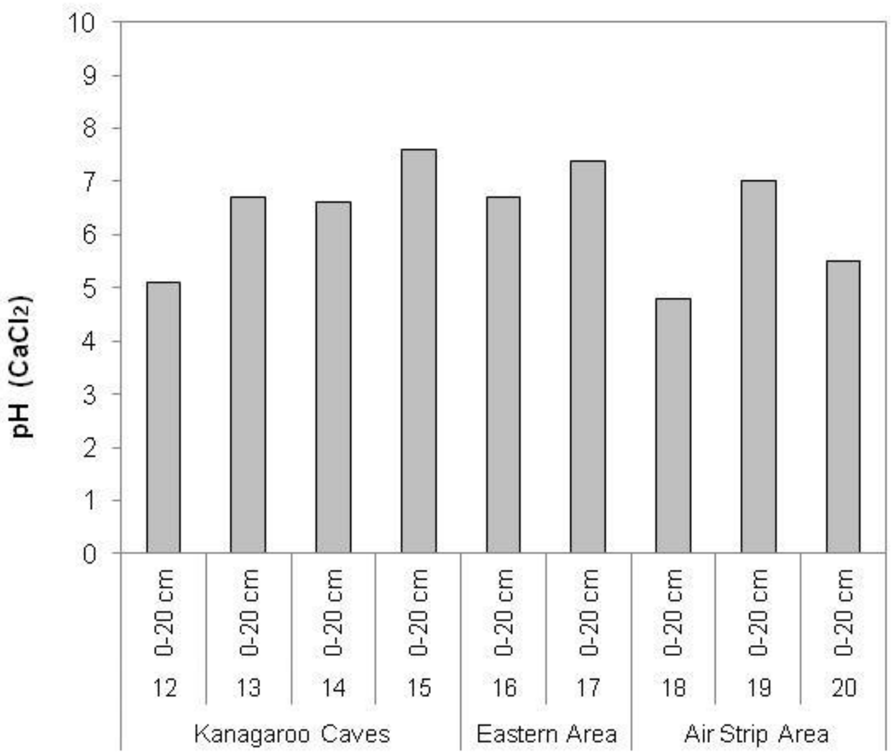


**Figure 32: Individual soil pH ($CaCl_2$) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

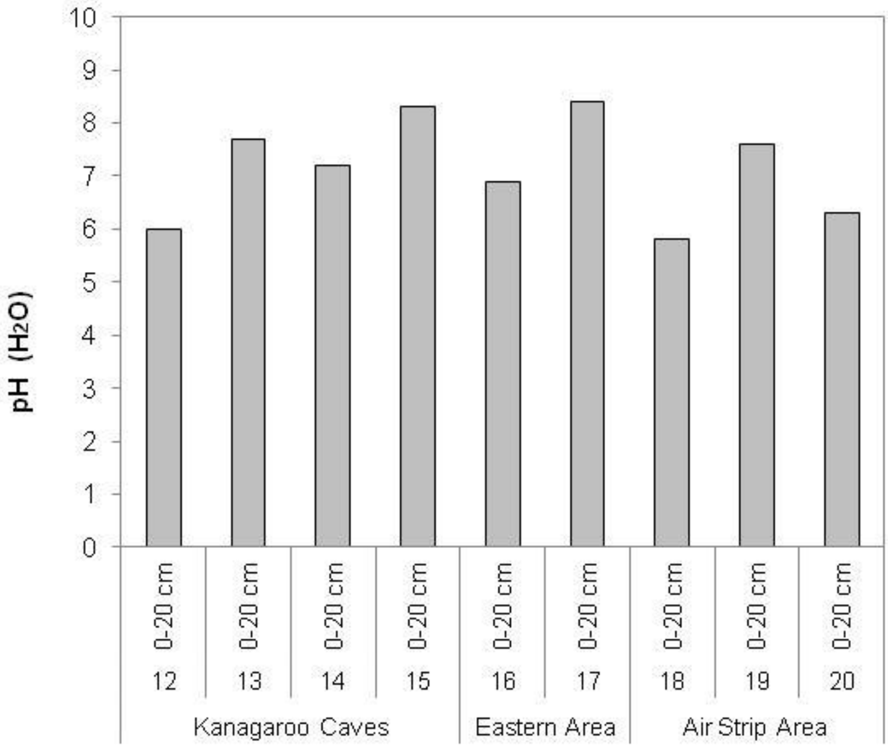


**Figure 33: Individual soil pH ($H_2O$) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

### 3.5.2 Electrical conductivity

The EC values of the soils sampled from the Kangaroo Caves, Eastern and Air Strip area ranged from 0.017 to 0.142 dS/m (**Figure 34**), with all samples classified as 'non-saline' based on the standard USDA and CSIRO categories (**Appendix B**). The majority of the 2011 and 2012 Project area soils were also 'non-saline'.

The low EC values indicate that there is a very low risk of salinity related issues occurring if the soils are stripped, stockpiled and used as a surface rehabilitation medium.

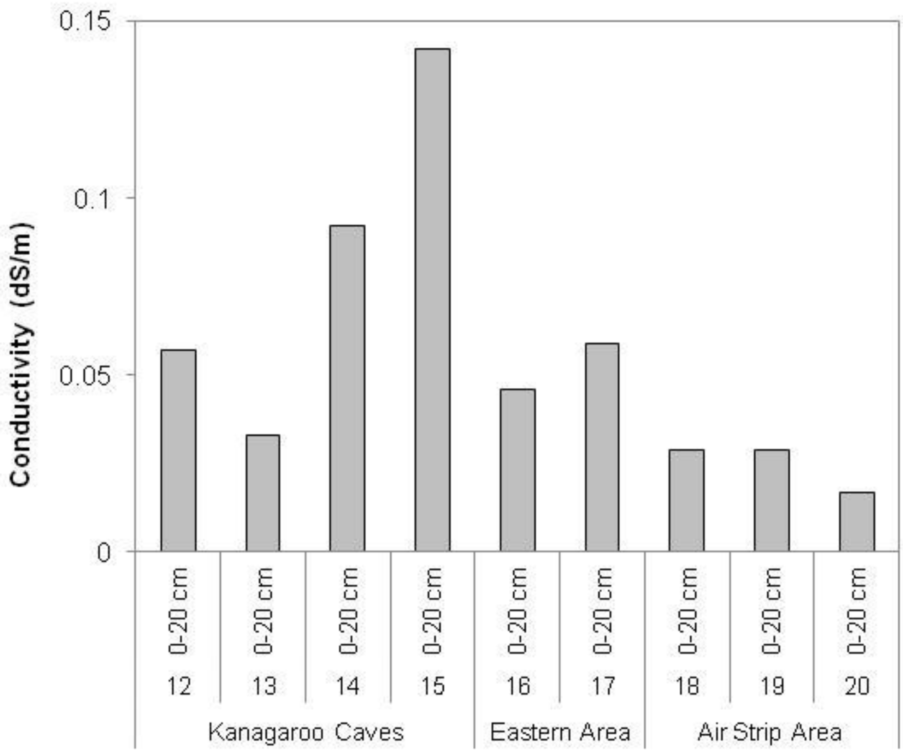


**Figure 34: Individual electrical conductivity (EC 1:5 $H_2O$) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

### 3.5.3 Soil organic carbon

The SOC% within the majority of the Kangaroo Caves, Eastern and Air Strip area soils was low (<1% SOC) (Moore 1998), as is the case in most natural Western Australian arid land soils, with individual values ranging between 0.20% and 1.47% (**Figure 35**). The organic carbon percentage for the 2011 and 2012 Project area soils was, overall, lower than that of the Kangaroo Caves, Eastern and Air Strip area soils.

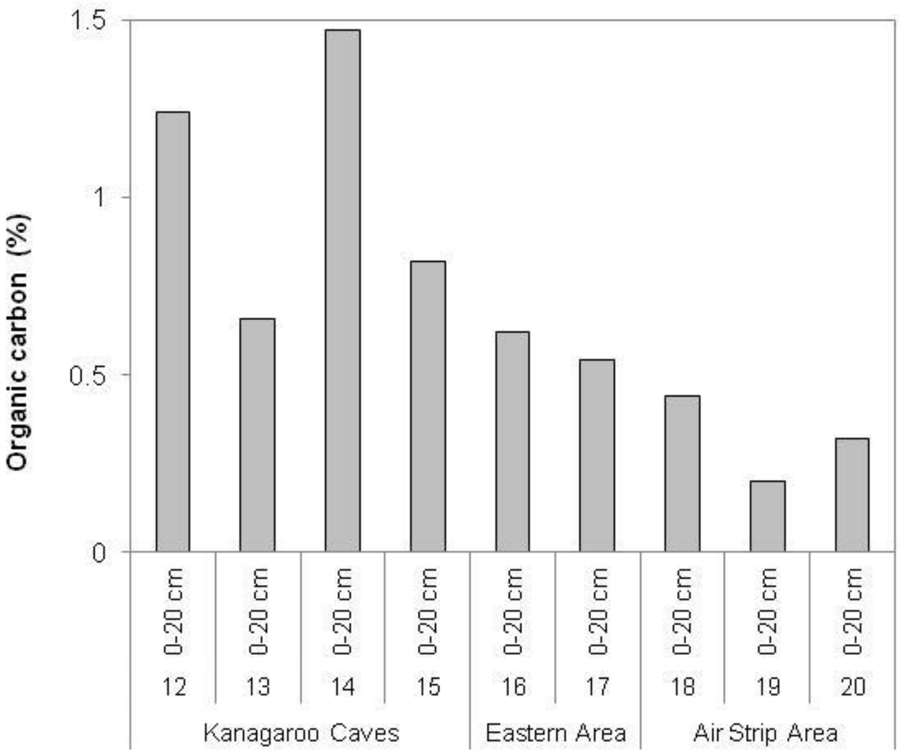


**Figure 35: Individual soil organic carbon (%) values for soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

### 3.5.4 Exchangeable cations and exchangeable sodium percentage (ESP)

All the soil samples (soil sized fraction) from within the Kangaroo Caves, Eastern and Air Strip area were classified as 'non-sodic' with exchangeable sodium values below the level of detection (**Table 13**). This indicates that the soils from the Kangaroo Caves, Eastern and Air Strip area are considered unlikely to be problematic from a clay dispersion and derived erodibility perspective. Care should be taken, however, to minimise the handling of the soil materials where possible, particularly when wet. The majority of the 2011 and 2012 Project area soils were also classified as 'non-sodic'.

**Table 13: Individual exchangeable sodium percentage (ESP) (%) and effective cation exchange capacity (eCEC) values for the soil sized fraction (<2 mm) of the Kangaroo Caves, Eastern and Air Strip areas of the Project area surface soil samples**

| Description | Site | Depth (cm) | ESP (%)[1] | eCEC (meq/100g) |
|---|---|---|---|---|
| Kanagaroo Caves area soil 2013 | SS12 | 0-20 | BDL | 3.09 |
| | SS13 | 0-20 | BDL | 10.95 |
| | SS14 | 0-20 | BDL | 12.07 |
| | SS15 | 0-20 | BDL | 11.08 |
| Eastern area soil 2013 | SS16 | 0-20 | BDL | 10.34 |
| | SS17 | 0-20 | BDL | 9.94 |
| Air Strip area soil 2013 | SS18 | 0-20 | BDL | 2.92 |
| | SS19 | 0-20 | BDL | 5.19 |
| | SS20 | 0-20 | BDL | 3.11 |

1. BDL: Exchangeable sodium below detection limit, assumed non-sodic.

### 3.5.5 Plant-available soil nutrients

#### *3.5.5.1* Plant-available nitrogen

Plant-available nitrogen values from the Kangaroo Caves, Eastern and Air Strip area soils was ranged from low (4 mg/kg) to relatively high (29 mg/kg) (**Figure 36**). The majority of the 2011 and 2012 Project area soils exhibited low plant-available nitrogen values.

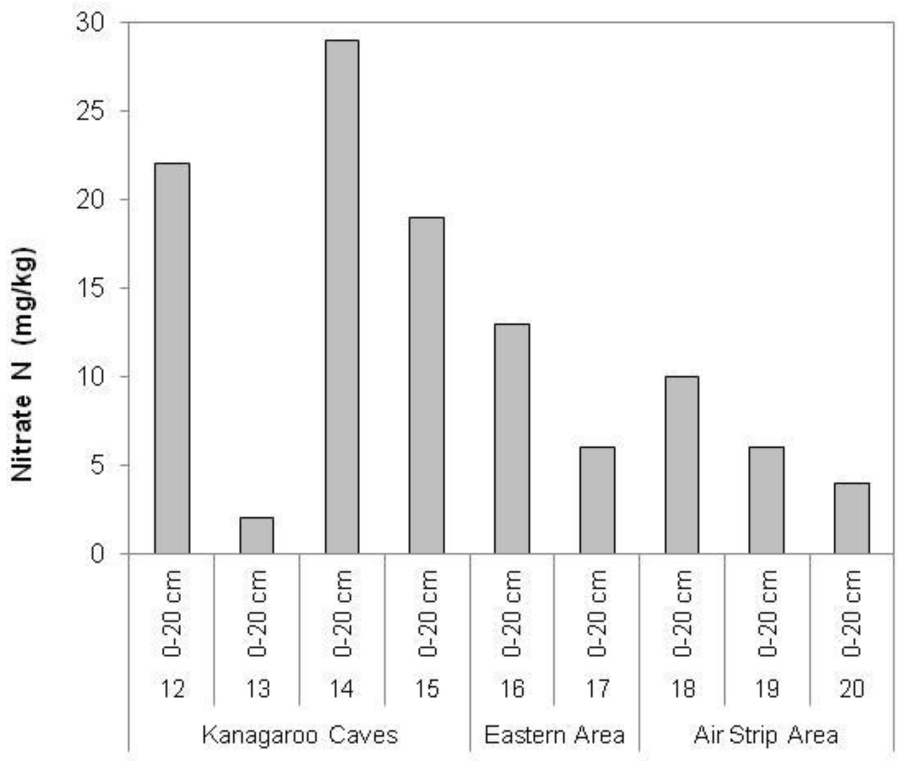


**Figure 36: Individual plant-available nitrogen (nitrate N) (mg/kg) values for soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

#### *3.5.5.2* Plant-available phosphorus

Plant-available phosphorus for all samples from the Kangaroo Caves, Eastern and Air Strip area was classed as 'low' (<10 mg/kg) (Moore 1998) with individual concentrations ranging from 3 mg/kg to 6 mg/kg (**Figure 37**). The 2011 and 2012 Project area soils also exhibited low plant-available phosphorus values.

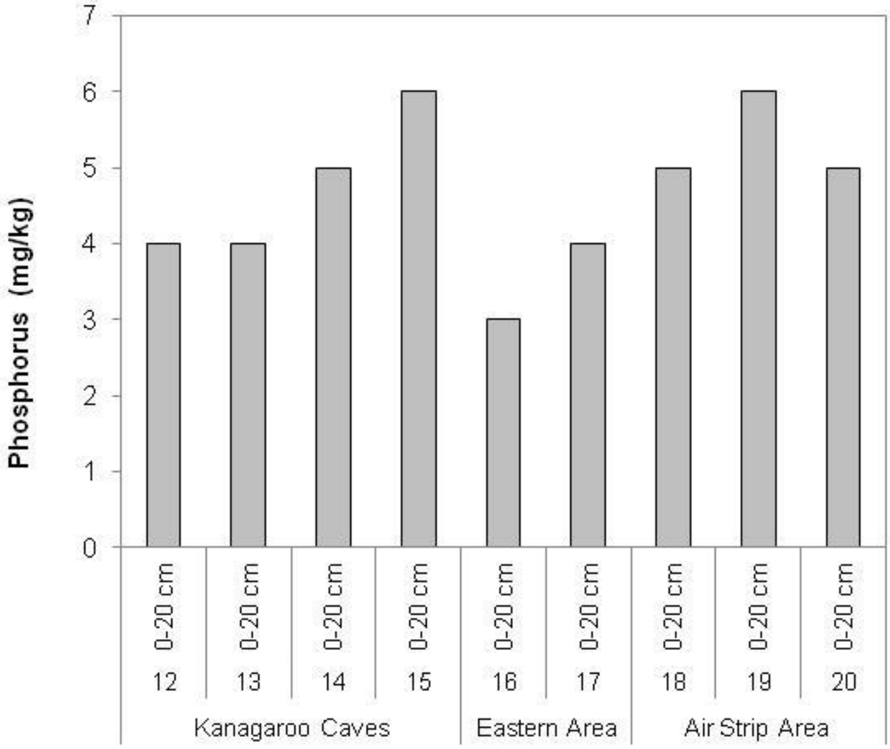


**Figure 37: Individual plant-available phosphorus (P) (mg/kg) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

*3.5.5.3* Plant-available potassium

Plant-available potassium within all soils sampled from the Kangaroo Caves, Eastern and Air Strip area was classed as 'high' (<200 mg/kg) (Moore 1998) ranging from 249 mg/kg to 553 mg/kg (**Figure 38**). The 2011 and 2012 Project area soils exhibited 'low' to 'high' plant-available potassium values.

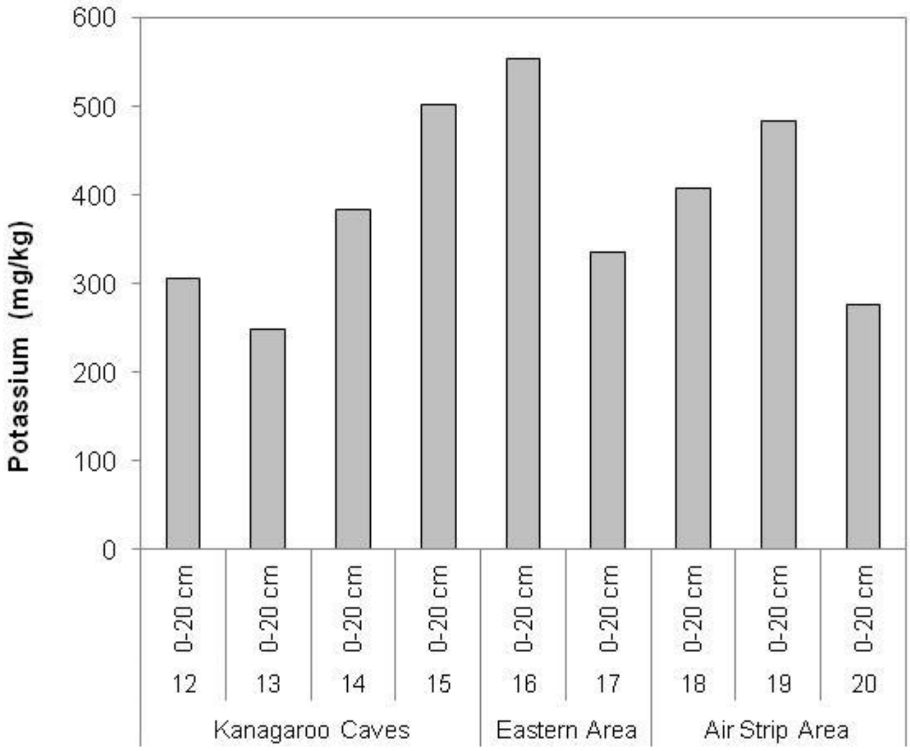


**Figure 38: Individual plant-available potassium (K) (mg/kg) values for soils from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

*3.5.5.4* Plant-available sulphur

Plant-available sulphur concentrations of the Kangaroo Caves, Eastern and Air Strip area soils were below 14 mg/kg (**Figure 39**). The plant-available sulphur values for the majority of the 2011 and 2012 Project area soils were below 20 mg/kg.

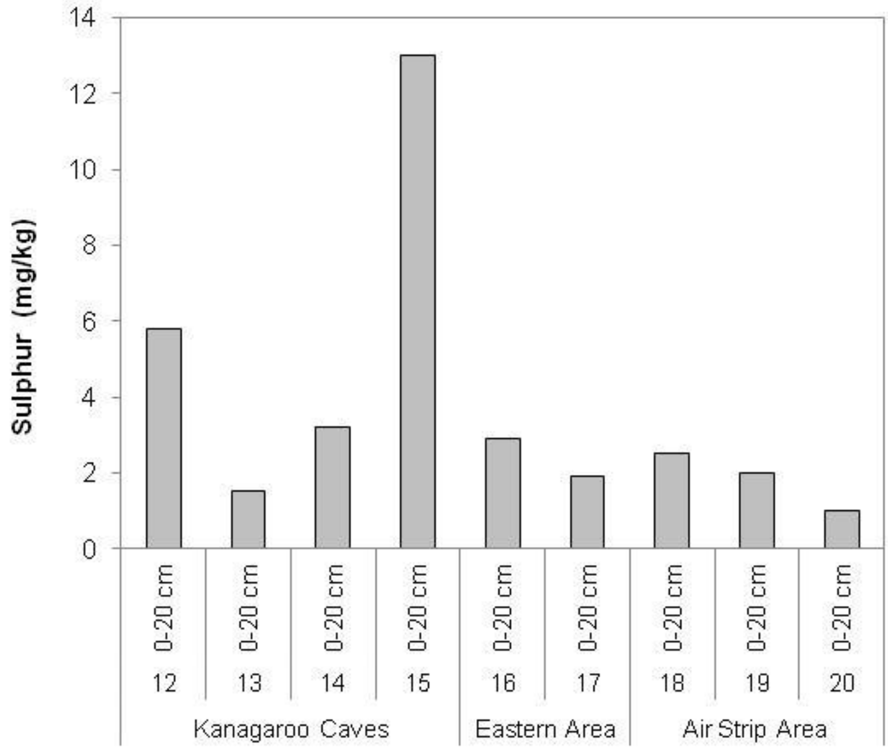


**Figure 39: Individual plant-available sulphur (S) (mg/kg) values for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

### 3.5.6 Total metal concentrations

Measurements of total metal concentrations of the Kangaroo Caves and Air Strip area soil samples indicated that variable levels of Cr, Cu, Ni, and Zn were present (**Table 14**). Most materials sampled were below the detectable limit of reporting (LOR) for As, Cd and Hg, and often below the LOR for Pb. Concentrations of Cr, Cu, Ni, Pb and Zn were regularly detected at a reportable level (**Table 14**).

All results were compared with 'Ecological Investigation Levels' (EILs) for soils (DEC 2010). The EILs are intended as a guide only, as higher EIL values may be acceptable for some metal concentrations, such as As, Cr, Cu, Ni, Pb and Zn, in areas where soils naturally have high background concentrations of these substances (DEC 2010). The levels of Ni were measured above the default EILs for soils (DEC 2010) in the majority of samples from the Kangaroo Caves and Air Strip areas (**Table 14**).

**Table 14: Individual total metal values (mg/kg) and limits of reporting (LOR) for soil samples from the Kangaroo Caves, Eastern and Air Strip areas of the Sulphur Springs Copper Zinc Project area**

| Description | Site | Depth (cm) | Analyte (mg/kg) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Arsenic | Cadmium | Chromium | Copper | Lead | Nickel | Zinc | Mercury |
| Kangaroo Caves area soil 2013 | SS12 | 0-20 | <5 | <1 | **128** | **20** | **6** | **52** | **42** | <0.1 |
| | SS13 | 0-20 | <5 | <1 | **211** | **45** | <5 | **171** | **129** | <0.1 |
| | SS14 | 0-20 | **7** | <1 | **454** | **56** | <5 | **243** | **127** | <0.1 |
| | SS15 | 0-20 | <5 | <1 | **266** | **42** | <5 | **195** | **130** | <0.1 |
| Eastern area soil 2013 | SS16 | 0-20 | <5 | <1 | **279** | **40** | <5 | **190** | **142** | <0.1 |
| | SS17 | 0-20 | <5 | <1 | **399** | **45** | <5 | **192** | **54** | <0.1 |
| Air Strip area soil 2013 | SS18 | 0-20 | <5 | <1 | **127** | **50** | **9** | **60** | **50** | <0.1 |
| | SS19 | 0-20 | <5 | <1 | **137** | **65** | **6** | **112** | **97** | <0.1 |
| | SS20 | 0-20 | <5 | <1 | **106** | **30** | **6** | **51** | **34** | <0.1 |
| **LOR (mg/kg)** | | | **5** | **1** | **2** | **5** | **5** | **2** | **5** | **0.1** |
| **EIL (mg/kg)** | | | **20** | **3** | **1* / 400^** | **100** | **600** | **60** | **200** | **1** |

Note: Values in bold indicate levels detected above Limits of Reporting (LOR), levels above the Ecological Investigation Levels (EIL) (DEC 2010) are highlighted in orange.
* = EIL for Chromium VI
^ = EIL for Chromium III

# 4. SOIL RESOURCE INVENTORY

An inventory of potentially available soil resources has been calculated from the approximate soil depth and spatial 'soil area' information supplied by Venturex personnel (**Table 15**).

The volume of soil associated with Site 5 (2012) has been removed from the soil resources inventory as the site occurs over a locally significant vegetation association (Outback Ecology 2013) and is also within close proximity of a short range endemic species pseudoscorpion *Feaella* PSE007 (Outback Ecology 2012).

**Table 15: Potential soil resources available within the Sulphur Springs Copper Zinc Project area**

| Description | Site | Approx. soil depth (m) [1] | Potential area of soil resources ($m^2$) [2] | Approximate volume of soil resources available ($m^3$) [3] |
|---|---|---|---|---|
| Project area soil 2012 | Site 1 | 0.7 | 44,919 | 31,443 |
| | Site 2 | 0.4 | 52,828 | 21,131 |
| | Site 3 | 1.0 | 15,013 | 15,013 |
| | Site 4 | 0.4 | 16,299 | 6,520 |
| | Site 5 * | 1.2 | 18,693 | - |
| | Site 6 | 1.0 | 16,755 | 16,755 |
| TSF Area B soil 2012 | Sites 7, 8 | 0.05 | 47,592 | 2,356 |
| TSF Area A soil 2012 | Sites 9, 10, 11 | 0.05 | 159,055 | 7,952 |
| Kangaroo Caves area soil 2013 | Site 12 | 0.3 | 47,592 | 14,278 |
| | Site 13 | 0.3 | 48,511 | 14,553 |
| | Site 14 | 0.5 | 33,940 | 16,970 |
| | Site 15 | 0.5 | 20,347 | 10,174 |
| Eastern area soil 2013 | Site 16 | 0.7 | no data | no data |
| | Site 17 | 0.7 | no data | no data |
| Air Strip area soil 2013 | Site 18 | 0.4 | 57,420 | 22,968 |
| | Site 19 | 2.0 | 157,731 | 315,462 |
| | Site 20 | 2.5 | 1,206,232 | 3,015,579 |
| **TOTAL** | | | | **3,511,155** |

1. Approximate depth of soil data supplied by Venturex personnel
2. Approximate area of soil as delineated in Figures 6, 7 & 8 (information supplied by Venturex)
3. Calculated from approximate depth of soil indicated

* Site 5 soil volume removed from inventory due to location in a sensitive area

# 5. CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Summary of soil characteristics

This section provides a summary of the characteristics of potential soil resources within the Sulphur Springs Copper Zinc Project area.

The physical and chemical characteristics of the 2011 and 2012 project area surface soils were:

- Soil textures ranging from ‘loamy sand’ to ‘sandy clay’ (5% to 29% clay);
- approximately 28% to 81% coarse material (>2 mm) with the majority >50%;
- ‘stable’ to ‘moderately stable’ from a structural stability perspective, although some partially dispersive soils identified;
- potentially hardsetting soils;
- predominantly ‘moderate’ to ‘moderately rapid’ drainage class;
- low water retention capacity;
- predominantly ‘non-saline’;
- ‘moderately acidic’ to ‘strongly alkaline’ pH;
- mostly “non-sodic”;
- predominantly ‘low’ organic carbon percentage;
- variable concentrations of plant-available nutrients (typical of regional soils); and
- variable concentrations of total metals (typical of regional soils).

The physical and chemical characteristics of the Kangaroo Caves, Eastern and Air Strip area surface soils were:

- Soil textures were all ‘sandy loam’ (13% to 15% clay);
- approximately 11% to 47% coarse material (>2 mm)
- ‘stable’ to ‘moderately stable’ from a structural stability perspective, although some partially dispersive soils identified;
- non-hardsetting soils;
- predominantly ‘moderate’ to ‘moderately rapid’ drainage class;
- low to medium water retention capacity;
- predominantly ‘non-saline’;
- ‘moderately acidic’ to ‘strongly alkaline’ pH;
- mostly “non-sodic”;
- predominantly ‘low’ organic carbon percentage;
- variable concentrations of plant-available nutrients (typical of regional soils); and
- variable concentrations of total metals (typical of regional soils).

The investigations into the soil resources present within the Project area indicates that, while there is substantial variation in many of the physical and chemical characteristics of the soils present, the majority are likely to be suitable for use as a component of the TSF cover / rehabilitation medium.

### 5.2 Use of soil resources as a component of the TSF cover

The proposed TSF cover design will incorporate a clay sealing layer above the compacted, dry-stacked tailings, a soil 'water storage' layer of and an outer 'erosion resistant' layer of rocky soil. The outer surface of the cover will be sloped to promote runoff of surface water during high intensity rainfall events.

Of primary interest to the Project is the availability of suitable soil materials for use as the store-release component of the proposed TSF cover system. The soil store-release layer of the TSF cover will need to be capable of holding water from the majority of rainfall events and resilient enough to shed water from high intensity rainfall events. The soil store-release component will also need to support the growth of native vegetation which will assist in the release of stored water, as will evaporation from the outer surface. The key characteristics of the soils are therefore their ability to accept and store rainfall, resist erosion by surface water flow and support vegetation.

The high coarse fragment content of the majority of soils from the 2011 and 2012 Project area, in combination with the 'moderate' to 'moderately rapid' drainage class and low levels of clay dispersion, indicate that the majority of these soils should be relatively resistant to erosion, provided that surface water flow is not concentrated in any areas of the surface cover. The water retention characteristics of these soils indicate that, assuming homogenous infiltration and water storage (i.e. no preferential flow), the soils have a USL, on average, of approximately 15% (by volume). This means that a 1.0 m depth of soil will hold approximately 150 mm of rainfall. These characteristics make the 2011 and 2012 Project area soils potentially suitable as an outer 'erosion resistant' soil cover layer.

In contrast, the Kangaroo Caves, Eastern and Air Strip area soils have a lower percentage of coarse rock, indicating they are likely to be more prone to erosion. These soils have a USL, on average, of approximately 23% (by volume). This means that a 1.0 m depth of soil will hold approximately 230 mm of rainfall. These characteristics make the Kangaroo Caves, Eastern and Air Strip area soils potentially suitable as a soil water storage layer situated below the outer, more rocky soils.

Regional rainfall data indicates that the 1 in 100 year 72 hour rainfall event is 379 mm (BoM 2012). A depth of soil for the outer rocky soil cover has been indicated as 1.0 m which, based on a USL of 15%, would hold approximately 150 mm of rainfall. In addition, a depth of soil for the water storage layer soil has been indicated as 3.0 m, which, based on a USL of 23%, would hold approximately 690 mm of rainfall. This assumes homogenous infiltration of rainfall, a negligible amount of existing water storage in the soil materials and no surface run-off. As the TSF cover will be designed to shed any rainfall which falls at a rate greater than the infiltration capacity of the surface soil materials, the indication of the required depth of soil is likely to be adequate.

Current data, supplied by Venturex personnel, indicates that further volumes of, as yet, unassessed soil materials within the Airstrip area. These soil resources may potentially provide a source of material suitable or the clay sealing component of the TSF cover. This will require further investigation as the Project develops.

The volume of soil materials which would potentially be required for the TSF covers at closure is detailed in **Table 16**. The data presented is for a 3.0 m depth of soil cover for each TSF.

**Table 16: Volume of soil potentially required for rehabilitation and closure of the Sulphur Springs Copper Zinc Project TSF areas**

| Rehabilitation area | Surface area ($m^2$) | Volume of soil required for 3.0 m cover depth ($m^3$) |
|---|---|---|
| **TSF Area A** | | |
| Upper surface | 111,131 | 333,392 |
| Sloped surface | 47,924 | 143,771 |
| **TSF Area B** | | |
| Upper surface | 34,175 | 102,526 |
| Sloped surface | 12,939 | 38,816 |
| | **Total** | **618,505** |

The current soil resources inventory for the Project area has identified an available volume of soil in the vicinity of 3,511,155 $m^3$ (**Section 4**), based on information supplied by Venturex personnel. There is therefore a surplus in the currently identified available soil resources required for the final cover, rehabilitation and closure of the TSFs.

### 5.3 Recommendations for further investigations

It is likely that further investigations will be required to potentially refine the proposed TSF cover design, rehabilitation protocols and associated mine closure criteria. Recommendations for further investigations include:

- further identification of a suitable source of clay materials, for the clay sealing layer, and geochemical assessment of the compacted permeability of those materials;
- identification of a suitable source of clean competent rock to enhance the armouring capacity and outer stability of the TSF cover;
- modelling of water balance of the TSF cover, expected runoff, drainage and sediment loss; and

- a commitment to establishment of field trials of TSF cover components, including evaluation of water storage capacity, erodibility and rehabilitation parameters (**Section 5.4** below).

A conceptual design of the field trials could be established to demonstrate a commitment to evaluation of TSF cover options.

### 5.4 Potential TSF cover field trial parameters

Potential cover parameters to be investigated at a 'field scale' could include:

- water infiltration and store-release characteristics of available soil cover materials;
- erodibility of outer layer soil / rock combinations;
- effectiveness of cover material combinations in reducing infiltration of water into underlying materials; and
- ability of outer soil cover materials to support vegetation growth.

The field trial would have to be established at a suitably large scale (i.e. over several hectares) to identify 'realistic' information on water storage and erodibility parameters. The cover treatments could be established on an existing slope, with monitoring of the soil water content (via sensors / loggers) through the constructed cover profiles, and surface soil loss (i.e. erodibility) from each treatment combination. The trial should be conducted for a number of years, to take as many climatic variables as possible into consideration.

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# Appendix A

# Glossary of terms

## Glossary of terms

***Aggregate (or ped)*** A cluster of primary particles separated from adjoining peds by natural planes of weakness, voids (cracks) or cutans.

***Bulk density*** Mass per unit volume of undisturbed soil, dried to a constant weight at 105°C.

***Clay*** The fraction of mineral soil finer than 0.002 mm (2 µm).

***Coarse fragments*** Particles greater than 2 mm in size.

***Consistence*** The strength of cohesion and adhesion in soil.

***Dispersion*** The process whereby the structure or aggregation of the soil is destroyed, breaking down into primary particles.

***Electrical conductivity*** How well a soil conducts an electrical charge, related closely to the salinity of a soil.

***Hydrophobicity*** Description of hydrophobic or water repellent characteristics in soil. Primarily caused by hydrophobic organic residues derived from decomposing plant materials, which alter the contact angle between water droplets and the soil surface, in turn affecting the ability of water to infiltrate into the soil.

***Massive soil structure*** Coherent soil, no soil structure, separates into fragments when displaced. Large force often required to break soil matrix.

***Modulus of Rupture (MOR)*** This test is a measure of soil strength and identifies the tendency of a soil to hard-set as a direct result of soil slaking and dispersion.

***Organic carbon*** Carbon residue retained by the soil in humus form. Can influence many physical, chemical and biological soil properties. Synonymous with organic matter (OM).

***Plant-available water*** The ability of a soil to hold that part of the water that can be absorbed by plant roots. Available water is the difference between field capacity and permanent wilting point.

| | |
|---|---|
| ***Regolith*** | The unconsolidated rock and weathered material above bedrock, including weathered sediments, saprolites, organic accumulations, soil, colluvium, alluvium and aeolian deposits. |
| ***Single grain structure*** | Loose, incoherent mass of individual particles. Soil separates into individual particles when displaced. |
| ***Slaking*** | The partial breakdown of soil aggregates in water due to the swelling of clay and the expulsion of air from pore spaces. |
| ***Soil horizon*** | Relatively uniform materials that extend laterally, continuously or discontinuously throughout the profile, running approximately parallel to the surface of the ground and differs from the related horizons in chemical, physical or biological properties. |
| ***Soil pH*** | The negative logarithm of the hydrogen ion concentration of a soil solution. The degree of acidity or alkalinity of a soil expressed in terms of the pH scale, from 2 to 10. |
| ***Soil structure*** | The distinctness, size, shape and arrangement of soil aggregates (or peds) and voids within a soil profile. Can be classed as *'apedal'*, having no observable peds, or *'pedal'*, having observable peds. |
| ***Soil strength*** | The resistance of a soil to breaking or deformation. '*Hardsetting'* refers to a high soil strength upon drying. |
| ***Soil texture*** | The size distribution of individual particles of a soil. |
| ***Subsoil*** | The layer of soil below the topsoil or A horizons, often of finer texture (i.e. more clayey), denser and stronger in colour. Generally considered to be the 'B-horizon' above partially weathered or un-weathered material. |
| ***Topsoil*** | Soil consisting of various mixtures of sand, silt, clay and organic matter; considered to be the nutrient-rich top layer of soil – The 'A-horizon'. |

# Appendix B

# Outback Ecology soil analysis methods

## Soil texturing

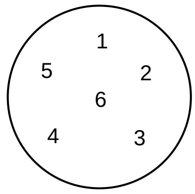
Soils were worked by hand, and the texture, shearing capacity, particle size and ribbon length were observed according to methods described in McDonald *et al.* (1998) as follows.

| Texture grade | Behaviour of moist bolus | Approximate clay content | Code |
|---|---|---|---|
| Sand | Nil to very slight coherence; cannot be moulded; single sand grains adhere to fingers | <5 % | S |
| Loamy sand | Slight coherence; can be sheared between thumb and forefinger to give minimal ribbon of about 5 mm | 5 % | LS |
| Clayey sand | Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with stain; forms minimal ribbon of 5 – 15 mm | 5 - 10 % | CS |
| Sandy loam | Bolus coherent but very sandy to touch; dominant sand grains of medium size and readily visible ; ribbon of 15 – 25 mm | 10 – 20 % | SL |
| Loam | Bolus coherent and rather spongy; no obvious sandiness or silkiness; forms ribbon of about 25 mm | 25 % | L |
| Sandy clay loam | Strongly coherent bolus; sandy to touch; ribbon of 25 – 40 mm | 20 - 30 % | SCL |
| Clay loam | Coherent plastic bolus, smooth to touch, ribbon of 25 mm to 40 mm | 30 – 35 % | CL |
| Clay loam, sandy | Coherent plastic bolus, sand grains visible in finer matrix, ribbon of 40 - 50 mm; sandy to touch | 30 - 35 % | CLS |
| Light clay | Plastic bolus, smooth to touch; slight resistance to shearing; ribbon of 50 – 75 mm | 35 – 40 % | LC |
| Light medium clay | Ribbon of about 75 mm, slight to moderate resistance to ribboning shear | 40 - 45 % | LMC |
| Medium clay | Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture; moderate resistance to ribboning shear, ribbon of 75 mm or longer | 45 – 55 % | MC |
| Medium heavy clay | Ribbon of 75 mm or longer, handles like plasticine, moderate to firm resistance to ribboning shear | >50 % | MHC |
| Heavy clay | Handles like stiff plasticine; firm resistance to ribboning shear, ribbon of 75 mm or longer | >50 % | HC |

## Emerson dispersion test

Emerson dispersion tests were carried out on all samples according to the following procedure:

1. A petri dish was labelled 1 to 6. eg.




2. The petri dish was filled with DI water.
3. A 3-5mm soil aggregate is taken from each sample and gently placed into the labelled petri dish (3 per dish).
4. Additional aggregates, remoulded by hand, are placed into the labelled petri dish (3 per dish).
5. Observations are made of the dispersivity or slaking nature of the sample according to the following table:

*Emerson Aggregate test classes (Moore 1998)*

| Class | Description |
|---|---|
| **Class 1** | Dry aggregate slakes and completely disperses |
| **Class 2** | Dry aggregate slakes and partly disperses |
| **Class 3a** | Dry aggregate slakes but does not disperse; remoulded soil disperses completely |
| **Class 3b** | Dry aggregate slakes but does not disperse; remoulded soil partly disperses |
| **Class 4** | Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are present |
| **Class 5** | Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are absent; 1:5 suspension remains dispersed |
| **Class 6** | Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are absent; 1:5 suspension remains flocculated |
| **Class 7** | Dry aggregate does not slake; aggregate swells |
| **Class 8** | Dry aggregate does not slake; aggregate does not swell |

The samples were left in the dish for a 24 hour period, after which the samples were observed again and rated according to the above Table.

### Soil electrical conductivity classes

(Based on standard USDA and CSIRO categories)

| EC (1:5) (dS/m) | | | | | | |
|---|---|---|---|---|---|---|
| **Salinity class** | **Sand** | **Sandy loam** | **Loam** | **Clay loam** | **Light / medium clay** | **Heavy clay** |
| Non-saline | <0.13 | <0.17 | <0.20 | <0.22 | <0.25 | <0.33 |
| Slightly saline | 0.13-0.26 | 0.17-0.33 | 0.20-0.40 | 0.22-0.44 | 0.25-0.50 | 0.33-0.67 |
| Moderately saline | 0.26-0.52 | 0.33-0.67 | 0.40-0.80 | 0.44-0.89 | 0.50-1.00 | 0.67-1.33 |
| Very saline | 0.52-1.06 | 0.67-1.33 | 0.80-1.60 | 0.89-1.78 | 1.00-2.00 | 1.33-2.67 |
| Extremely saline | >1.06 | >1.33 | >1.60 | >1.78 | >2.00 | >2.67 |

## Root abundance scoring

Root abundance is scored on a visual basis within the categories defined by McDonald *et al.* 1998:

| **Score** | **Roots per 10 $cm^2$** | |
|---|---|---|
| | *Very fine and fine roots* | *Medium and coarse roots* |
| 0 – No roots | 0 | 0 |
| 1 – Few | 1 - 10 | 1 or 2 |
| 2 – Common | 10 - 25 | 2 – 5 |
| 3 – Many | 25 - 200 | >5 |
| 4 - Abundant | >200 | >5 |

## General soil pH ratings

These ratings area based on the Land Evaluation Standards for Land Resource Mapping categories, (Van Gool *et. al*. 2005).

The pH of a soil measures its acidity or alkalinity. The standard method for measuring pH in WA is 1:5 0.01M $CaCl_2$ ($pH_{Ca}$). However, in most land resource surveys it has been measured in a 1:5 soil:water suspension ($pH_w$). It is preferable to record actual data rather than derived data, therefore pH should be recorded according to the method used. The pH measured using different methods should not be compared directly for site investigations. For general land interpretation purposes, the relationship between $pH_w$ and $pH_{Ca}$ can be estimated by the equation:

$$pH_{Ca} = 1.04\ pH_w - 1.28$$ (Van Gool *et. al*. 2005)

The most widely available pH measurement is for the surface layer. However, the pH of the topsoil varies dramatically, and based on a comparison of map unit and soil profile data, estimated mean values for topsoil pH is commonly underestimated. Hence it is suggested that only an estimate of subsoil pH should be attempted. Even for subsoil the value can only be used as an indicator because pH varies dramatically with land use and minor soil variations.

### Soil depth

The pH should be recorded for each soil group layer. It is then reported at the following predefined depths:

- 0 - 10 cm (the surface layer);
- 20 cm (used for assessing subsoil acidity); and
- 50 - 80 cm. If there is a layer boundary within this depth use the higher value (used for assessing subsoil alkalinity).

| | **Soil pH rating** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Very strongly acid (Vsac)** | **Strongly acid (Sac)** | **Moderately acid (Mac)** | **Slightly acid (Slac)** | **Neutral (N)** | **Moderately alkaline (Malk)** | **Strongly alkaline (Salk)** |
| **$pH_w$** | < 5.3 | 5.3 - 5.6 | 5.6 - 6.0 | 6.0 - 6.5 | 6.5 - 8.0 | 8.0 - 9.0 | > 9.0 |
| **$pH_{Ca}$** | < 4.2 | 4.2 - 4.5 | 4.5 - 5.0 | 5.0 - 5.5 | 5.5 - 7.0 | 7.0 - 8.0 | > 8.0 |

# Appendix C

## Outback Ecology soil analysis results

**Summary of Outback Ecology results for hand texture, coarse fraction content, Emerson Class and soil strength (Modulus of Rupture)**

| Description | Site | Sample depth interval (cm) | Hand texture (<2 mm fraction) | % Coarse material (>2 mm) | Emerson Test Class | MOR (kPa) |
|---|---|---|---|---|---|---|
| Project area soil 2011 | Site A1 | 0-5 | Clayey sand | 67 | 3b | 52.9 |
| | | 10-20 | Clayey sand | 81 | 3b | 72.3 |
| | | 40-50 | Clayey sand | 75 | 3b | 111.5 |
| | Site A2 | 0-5 | Clayey sand | 63 | 5 | 44.6 |
| | | 10-20 | Clayey sand | 77 | 6 | 36.6 |
| | | 40-50 | Clayey sand | 71 | 6 | 33.5 |
| | Site A3 | 0-5 | Clayey sand | 70 | 2 | 68.8 |
| | | 10-20 | Clayey sand | 71 | 2 | 115.1 |
| | | 40-50 | Clayey sand | 71 | 2 | 146.7 |
| | Site A4 | 0-5 | Sandy clay loam | 67 | 2 | 126.8 |
| | | 10-20 | Clay loam | 58 | 6 | 130.2 |
| | | 40-50 | Sandy loam | 43 | 6 | 42.2 |
| | Site A5 | 0-5 | Sandy loam | 65 | 3b | 57.5 |
| | | 10-20 | Sandy loam | 59 | d | 87.2 |
| | Site A6 | 0-5 | Loam | 49 | 5 | 23.0 |
| | | 10-20 | Sandy clay loam | 69 | 5 | 72.9 |
| Project area soil 2012 | Site 1 | 0-20 | Sandy clay loam | 60 | 8 | 52.5 |
| | | 40-60 | Clay loam sandy | 56 | 4 | 63.7 |
| | Site 2 | 0-20 | Sandy clay loam | 76 | 3b | 81.9 |
| | Site 3 | 0-20 | Clay loam sandy | 73 | 8 | 194.3 |
| | | 40-60 | Light clay | 28 | 2 | 394.5 |
| | Site 4 | 0-20 | Light clay | 57 | 3a | 76.2 |
| | Site 5 | 0-20 | Sandy loam | 34 | 5 | 42.4 |
| | | 40-60 | Clay loam sandy | 51 | 4 | 161.1 |
| | | 100-120 | Sand | 68 | 5 | 23.6 |
| | Site 6 | 0-20 | Clay loam sandy | 74 | 3b | 153.3 |
| | | 40-60 | Clay loam sandy | 63 | 3b | 237.3 |
| TSF Area B footprint soil 2012 | Site 7 | 0-5 | Sandy clay loam | 61 | 3b | 73.7 |
| | Site 8 | 0-5 | Sandy clay loam | 80 | 3a | 153.8 |
| TSF Area A footprint soil 2012 | Site 9 | 0-5 | Sandy clay loam | 71 | 2 | 135.7 |
| | Site 10 | 0-5 | Clay loam sandy | 68 | 2 | 180.9 |
| | Site 11 | 0-5 | Clay loam sandy | 68 | 3a | 143.8 |

| Description | Site | Sample depth interval (cm) | Hand texture (<2 mm fraction) | % Coarse material (>2 mm) | Emerson Test Class | MOR (kPa) |
|---|---|---|---|---|---|---|
| Kangaroo Caves area soil 2013 | SS12 | 0-20 | - | 43 | 3b | 9.9 |
| | SS13 | 0-20 | - | 47 | 5 | 31.9 |
| | SS14 | 0-20 | - | 13 | 5 | 20.1 |
| | SS15 | 0-20 | - | 22 | 3b | 15.1 |
| Eastern area soil 2013 | SS16 | 0-20 | - | 11 | 8 | 12.1 |
| | SS17 | 0-20 | - | 18 | 4 | 11.0 |
| Air Strip area soil 2013 | SS18 | 0-20 | - | 17 | 2 | 34.7 |
| | SS19 | 0-20 | - | 19 | 2 | 63.8 |
| | SS20 | 0-20 | - | 22 | 2 | 23.3 |

# Appendix D
# CSBP analysis results

## Table D1: Summary of CSBP analyses

| Sample ID | Depth (cm)/ Group | Texture | Gravel (%) | Ammonium Nitrogen | Nitrate Nitrogen | Phosphorus Colwell | Potassium Colwell | Sulphur | Organic Carbon | Conductivity | pH Level ($CaCl_2$) | pH Level ($H_2O$) | Particle size distribution: % Clay | % Course Sand | % Fine Sand | % Sand | % Silt | Exchangeable cations: Prewash exch. Ca | Prewash exch. K | Prewash exch. Mg | Prewash exch. Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mg / kg | mg / kg | mg / kg | mg / kg | mg / kg | % | dS / m | pH | pH | % | % | % | % | % | meq / 100g | meq / 100g | meq / 100g | meq / 100g |
| A SS01 | 0-5 | 2.5 | 25-30 | < 1 | 2 | 10 | 154 | 2.6 | 0.43 | 0.021 | 5.5 | 6.7 | 13.13 | 45.69 | 29.30 | 74.99 | 11.88 | 1.83 | 0.17 | 1.35 | <0.10 |
| A SS01 | 10-20 | 3.0 | 45-50 | < 1 | 4 | 5 | 151 | 5.2 | 0.18 | 0.020 | 5.4 | 6.4 | - | - | - | - | - | 1.47 | 0.19 | 1.24 | <0.10 |
| A SS01 | 40-50 | 3.0 | 35-40 | < 1 | 6 | 4 | 147 | 4.6 | 0.17 | 0.026 | 5.5 | 6.5 | - | - | - | - | - | 1.83 | 0.19 | 1.55 | <0.10 |
| A SS02 | 0-5 | 3.0 | 35-40 | < 1 | < 1 | 7 | 104 | 10.2 | 0.41 | 0.036 | 4.8 | 5.7 | - | - | - | - | - | 0.71 | 0.11 | 0.67 | <0.10 |
| A SS02 | 10-20 | 3.0 | 45-50 | 1 | < 1 | 6 | 94 | 13.3 | 0.12 | 0.016 | 4.6 | 5.6 | 20.92 | 43.82 | 23.45 | 67.27 | 11.81 | 0.80 | 0.12 | 0.66 | <0.10 |
| A SS02 | 40-50 | 3.0 | 25-30 | 1 | < 1 | 5 | 83 | 18.2 | 0.12 | 0.014 | 4.5 | 5.4 | - | - | - | - | - | 0.79 | 0.11 | 0.70 | <0.10 |
| A SS03 | 0-5 | 3.0 | 25-30 | 1 | < 1 | 10 | 100 | 14 | 0.18 | 0.069 | 5.9 | 6.9 | - | - | - | - | - | 0.46 | 0.11 | 0.78 | 0.12 |
| A SS03 | 10-20 | 3.0 | 25-30 | < 1 | < 1 | 5 | 40 | 7.7 | 0.12 | 0.046 | 6.1 | 7.1 | - | - | - | - | - | 0.35 | 0.68 | 0.95 | 0.15 |
| A SS03 | 40-50 | 3.0 | 35-40 | 1 | < 1 | 5 | 38 | 14.7 | 0.15 | 0.068 | 6.1 | 7.3 | 20.69 | 46.22 | 24.00 | 70.22 | 9.08 | 0.20 | 0.04 | 0.98 | 0.20 |
| A SS04 | 0-5 | 3.0 | 15-20 | 2 | 29 | 9 | 140 | 167.3 | 0.15 | 1.511 | 7.3 | 7.6 | - | - | - | - | - | 2.82 | 0.18 | 4.21 | 0.18 |
| A SS04 | 10-20 | 3.0 | 15-20 | 4 | 57 | 5 | 99 | 626.7 | 0.23 | 3.415 | 7.3 | 7.5 | - | - | - | - | - | 3.75 | 0.12 | 5.67 | 0.37 |
| ASS04 | 40-50 | 3.0 | 5-10 | 3 | 54 | 5 | 93 | 1645.7 | 0.22 | 3.930 | 7.5 | 7.7 | - | - | - | - | - | 7.73 | 0.11 | 4.83 | 0.46 |
| A SS05 | 0-5 | 3.0 | 35-40 | < 1 | < 1 | 8 | 108 | 3.6 | 0.51 | 0.012 | 4.6 | 5.5 | - | - | - | - | - | 0.56 | 0.08 | 0.58 | <0.10 |
| A SS05 | 10-20 | 3.0 | 35-40 | 1 | < 1 | 5 | 73 | 3.2 | 0.27 | 0.060 | 5.0 | 5.8 | - | - | - | - | - | 0.65 | 0.08 | 0.97 | <0.10 |
| A SS06 | 0-5 | 3.0 | 5-10 | 3 | < 1 | 10 | 133 | 3.5 | 0.25 | 0.015 | 5.0 | 6.0 | - | - | - | - | - | 1.02 | 0.15 | 1.29 | <0.10 |
| A SS06 | 10-20 | 3.0 | 15-20 | 1 | < 1 | 6 | 118 | 16.9 | 0.18 | 0.028 | 5.0 | 6.0 | - | - | - | - | - | 1.18 | 0.17 | 1.88 | <0.10 |
| SS01 | 0-20 | 2 | 0 | 3 | < 1 | 6 | < 15 | 4.7 | 0.72 | 0.098 | 8.0 | 8.5 | 11.96 | 57.40 | 17.62 | 75.02 | 13.02 | 7.58 | 0.13 | 3.23 | <0.10 |
| SS01 | 40-60 | 2 | 0 | 4 | < 1 | < 2 | 48 | 1.3 | 0.24 | 0.101 | 8.2 | 9.0 | 7.52 | 39.34 | 35.18 | 74.52 | 17.97 | 4.07 | 0.04 | 4.38 | <0.10 |

| Sample ID | Depth (cm)/ Group | Texture | Gravel (%) | Ammonium Nitrogen | Nitrate Nitrogen | Phosphorus Colwell | Potassium Colwell | Sulphur | Organic Carbon | Conductivity | pH Level ($CaCl_2$) | pH Level ($H_2O$) | Particle size distribution | | | | | Exchangeable cations | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | % Clay | % Course Sand | % Fine Sand | % Sand | % Silt | Prewash exch. Ca | Prewash exch. K | Prewash exch. Mg | Prewash exch. Na |
| | | | | mg / kg | mg / kg | mg / kg | mg / kg | mg / kg | % | dS / m | pH | pH | % | % | % | % | % | meq / 100g | meq / 100g | meq / 100g | meq / 100g |
| SS02 | 0-20 | 1.5 | 0 | 7 | < 1 | < 2 | 129 | 3.5 | 0.45 | 0.02 | 5.8 | 6.3 | 19.47 | 56.53 | 18.15 | 74.68 | 5.86 | 0.73 | 0.08 | 0.43 | <0.10 |
| SS03 | 0-20 | 2.5 | 0 | 2 | 2 | 3 | 121 | 52.9 | 0.85 | 0.476 | 7.4 | 7.8 | 18.79 | 25.59 | 33.80 | 59.38 | 21.82 | 2.06 | 0.1 | 3.07 | 0.11 |
| SS03 | 40-60 | 2.5 | 0 | 2 | 2 | < 2 | 34 | 594.8 | 0.10 | 1.764 | 7.9 | 8.6 | 21.92 | 16.67 | 23.46 | 40.14 | 37.94 | 1.98 | 0.04 | 3.38 | 0.38 |
| SS04 | 0-20 | 3 | 0 | 2 | 3 | < 2 | 404 | 3.6 | 0.46 | 0.042 | 7.1 | 7.8 | 28.24 | 34.82 | 27.19 | 62.01 | 9.75 | 5.85 | 0.46 | 3.80 | <0.10 |
| SS05 | 0-20 | 3.5 | 0 | 6 | 5 | < 2 | 361 | 11.1 | 0.95 | 0.148 | 7.5 | 8.0 | 16.21 | 40.05 | 32.26 | 72.31 | 11.48 | 5.05 | 0.32 | 2.13 | <0.10 |
| SS05 | 40-60 | 3 | 0 | 4 | 3 | < 2 | 190 | 9.5 | 0.20 | 0.121 | 8.3 | 9.2 | 19.64 | 30.04 | 22.76 | 52.80 | 27.56 | 3.56 | 0.17 | 4.69 | <0.10 |
| SS05 | 100-120 | 3 | 0 | 3 | 3 | < 2 | 146 | 31.8 | 0.24 | 0.199 | 8.2 | 8.9 | 4.83 | 54.73 | 32.64 | 87.37 | 7.80 | 2.76 | 0.17 | 6.29 | 0.23 |
| SS06 | 0-20 | 3 | 0 | 2 | 2 | < 2 | 310 | 1.5 | 0.19 | 0.034 | 6.6 | 7.2 | 26.62 | 32.77 | 25.80 | 58.57 | 14.81 | 2.63 | 0.34 | 2.15 | <0.10 |
| SS06 | 40-60 | 3 | 0 | 2 | 2 | < 2 | 331 | 1.0 | 0.15 | 0.027 | 6.7 | 7.3 | 29.02 | 31.60 | 29.35 | 60.95 | 10.03 | 4.48 | 0.36 | 3.29 | <0.10 |
| SS07 | 0-5 | 3 | 0 | 4 | 8 | 9 | 194 | 3.7 | 0.78 | 0.069 | 6.9 | 7.4 | 14.98 | 42.18 | 31.81 | 74.00 | 11.02 | 2.47 | 0.11 | 1.17 | <0.10 |
| SS08 | 0-5 | 3 | 0 | 2 | 4 | 4 | 267 | 1.5 | 0.92 | 0.018 | 5.6 | 6.3 | 17.31 | 40.13 | 31.95 | 72.08 | 10.61 | 2.59 | 0.20 | 1.09 | <0.10 |
| SS09 | 0-5 | 3 | 0 | 3 | 7 | 3 | 190 | 3.2 | 0.66 | 0.054 | 6.1 | 6.9 | 18.43 | 31.81 | 37.11 | 68.92 | 12.65 | 1.67 | 0.15 | 1.15 | <0.10 |
| SS10 | 0-5 | 3 | 0 | 6 | 5 | 5 | 276 | 3.6 | 1.02 | 0.064 | 6.5 | 7.1 | 18.87 | 29.55 | 37.64 | 67.19 | 13.94 | 2.75 | 0.17 | 1.20 | <0.10 |
| SS11 | 0-5 | 2.5 | 0 | 2 | 7 | 3 | 143 | 3.9 | 0.89 | 0.033 | 5.5 | 6.3 | 14.40 | 34.54 | 36.61 | 71.15 | 14.45 | 1.07 | 0.09 | 1.05 | <0.10 |
| SS12 | 0-20 | 2.0 | 0 | 14 | 22 | 4 | 306 | 5.8 | 1.24 | 0.057 | 5.1 | 6.0 | 11.81 | 62.30 | 18.97 | 81.27 | 6.92 | 1.65 | 0.31 | 1.13 | <0.10 |
| SS13 | 0-20 | 2.0 | 5-10 | 2 | 2 | 4 | 249 | 1.5 | 0.66 | 0.033 | 6.7 | 7.7 | 13.10 | 59.10 | 22.15 | 81.24 | 5.66 | 8.65 | 0.23 | 2.07 | <0.10 |
| SS14 | 0-20 | 2.0 | 0 | 3 | 29 | 5 | 383 | 3.2 | 1.47 | 0.092 | 6.6 | 7.2 | 12.95 | 58.92 | 20.68 | 79.60 | 7.45 | 8.89 | 0.32 | 2.86 | <0.10 |
| SS15 | 0-20 | 2.0 | 5 | 8 | 19 | 6 | 502 | 13.0 | 0.82 | 0.142 | 7.6 | 8.3 | 11.76 | 61.66 | 18.68 | 80.34 | 7.91 | 8.23 | 0.45 | 2.40 | <0.10 |
| SS16 | 0-20 | 2.0 | 0 | 5 | 13 | 3 | 553 | 2.9 | 0.62 | 0.046 | 6.7 | 6.9 | 11.57 | 73.12 | 11.42 | 84.54 | 3.89 | 7.16 | 0.36 | 2.82 | <0.10 |

| Sample ID | Depth (cm)/ Group | Texture | Gravel (%) | Ammonium Nitrogen | Nitrate Nitrogen | Phosphorus Colwell | Potassium Colwell | Sulphur | Organic Carbon | Conductivity | pH Level ($CaCl_2$) | pH Level ($H_2O$) | Particle size distribution | | | | | Exchangeable cations | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | % Clay | % Course Sand | % Fine Sand | % Sand | % Silt | Prewash exch. Ca | Prewash exch. K | Prewash exch. Mg | Prewash exch. Na |
| | | | | mg / kg | mg / kg | mg / kg | mg / kg | mg / kg | % | dS / m | pH | pH | % | % | % | % | % | meq / 100g | meq / 100g | meq / 100g | meq / 100g |
| SS17 | 0-20 | 2.0 | 5 | 3 | 6 | 4 | 336 | 1.9 | 0.54 | 0.059 | 7.4 | 8.4 | 13.31 | 48.61 | 32.33 | 80.94 | 5.75 | 8.59 | 0.24 | 1.11 | <0.10 |
| SS18 | 0-20 | 2.5 | 25-30 | 3 | 10 | 5 | 407 | 2.5 | 0.44 | 0.029 | 4.8 | 5.8 | 17.50 | 61.35 | 14.33 | 75.68 | 6.82 | 1.67 | 0.39 | 0.86 | <0.10 |
| SS19 | 0-20 | 2.5 | 5 | 2 | 6 | 6 | 483 | 2.0 | 0.20 | 0.029 | 7.0 | 7.6 | 12.84 | 67.59 | 14.60 | 82.20 | 4.96 | 2.07 | 0.36 | 2.76 | <0.10 |
| SS20 | 0-20 | 2.5 | 5-10 | 2 | 4 | 5 | 277 | 1.0 | 0.32 | 0.017 | 5.5 | 6.3 | 14.64 | 69.36 | 12.09 | 81.45 | 3.92 | 1.62 | 0.24 | 1.25 | <0.10 |

# Appendix E
## ALS Certificates of Analysis

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **EP1200088** | Page | : 1 of 4 |
| Client | : **OUTBACK ECOLOGY SERVICES** | Laboratory | : Environmental Division Perth |
| Contact | : ANNE BYRNE | Contact | : Scott James |
| Address | : 1/71 TROY TERRACE<br>JOLIMONT WA, AUSTRALIA 6014 | Address | : 10 Hod Way Malaga WA Australia 6090 |
| E-mail | : anna.byrne@outbackecology.com | E-mail | : perth.enviro.services@alsglobal.com |
| Telephone | : +61 08 93888799 | Telephone | : +61-8-9209 7655 |
| Facsimile | : +61 08 93888633 | Facsimile | : +61-8-9209 7600 |
| Project | : WHIM-SS-11002 | QC Level | : NEPM 1999 Schedule B(3) and ALS QCS3 requirement |
| Order number | : OES 2807 | | |
| C-O-C number | : ---- | Date Samples Received | : 06-JAN-2012 |
| Sampler | : AB | Issue Date | : 12-JAN-2012 |
| Site | : ---- | | |
| | | No. of samples received | : 16 |
| Quote number | : EP/615/11 | No. of samples analysed | : 10 |

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

## *Signatories*

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

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Canhuang Ke | Metals Instrument Chemist | Perth Inorganics |

## General Comments

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

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

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

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

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

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

## Analytical Results

Sub-Matrix: **SOIL**

| | | | Client sample ID | WIVXR01 0-5 | WIVXR01 40-50 | WIVXR02 0-5 | WIVXR02 40-50 | WIVXR03 0-5 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [06-JAN-2012] | [06-JAN-2012] | [06-JAN-2012] | [06-JAN-2012] | [06-JAN-2012] |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **EP1200088-001** | **EP1200088-003** | **EP1200088-004** | **EP1200088-006** | **EP1200088-007** |
| **EA055: Moisture Content** | | | | | | | | |
| **Moisture Content (dried @ 103°C)** | ---- | 1.0 | % | <1.0 | **1.7** | <1.0 | **2.9** | <1.0 |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| **Arsenic** | 7440-38-2 | 5 | mg/kg | <5 | <5 | <5 | <5 | <5 |
| **Cadmium** | 7440-43-9 | 1 | mg/kg | **3** | **3** | **2** | **2** | **2** |
| **Chromium** | 7440-47-3 | 2 | mg/kg | **76** | **93** | **83** | **73** | **54** |
| **Copper** | 7440-50-8 | 5 | mg/kg | **23** | **32** | **30** | **19** | **14** |
| **Lead** | 7439-92-1 | 5 | mg/kg | **7** | **12** | **22** | **12** | **6** |
| **Nickel** | 7440-02-0 | 2 | mg/kg | **47** | **73** | **27** | **20** | **15** |
| **Zinc** | 7440-66-6 | 5 | mg/kg | **202** | **262** | **39** | **24** | **34** |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |

## Analytical Results

Sub-Matrix: **SOIL**

| Compound | CAS Number | LOR | Unit | WIVXR03 40-50 | WIVXR04 0-5 | WIVXR04 40-50 | WIVXR05 0-5 | WIVXR06 0-5 |
|---|---|---|---|---|---|---|---|---|
| Client sampling date / time | | | | [06-JAN-2012] | [06-JAN-2012] | [06-JAN-2012] | [06-JAN-2012] | [06-JAN-2012] |
| | | | | EP1200088-009 | EP1200088-010 | EP1200088-012 | EP1200088-013 | EP1200088-015 |
| **EA055: Moisture Content** | | | | | | | | |
| Moisture Content (dried @ 103°C) | ---- | 1.0 | % | **1.9** | <1.0 | **3.6** | <1.0 | <1.0 |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| Arsenic | 7440-38-2 | 5 | mg/kg | <5 | <5 | <5 | <5 | <5 |
| Cadmium | 7440-43-9 | 1 | mg/kg | **2** | **2** | <1 | **1** | **2** |
| Chromium | 7440-47-3 | 2 | mg/kg | **56** | **73** | **39** | **71** | **186** |
| Copper | 7440-50-8 | 5 | mg/kg | **18** | **32** | **30** | **21** | **32** |
| Lead | 7439-92-1 | 5 | mg/kg | **7** | **8** | **5** | **23** | **8** |
| Nickel | 7440-02-0 | 2 | mg/kg | **31** | **42** | **40** | **19** | **44** |
| Zinc | 7440-66-6 | 5 | mg/kg | **43** | **52** | **44** | **46** | **58** |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |

ALS Group

Environmental Division

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **EP1210107** | Page | : 1 of 6 |
| Client | : **OUTBACK ECOLOGY SERVICES** | Laboratory | : Environmental Division Perth |
| Contact | : ANNE BYRNE | Contact | : Scott James |
| Address | : 1/71 TROY TERRACE<br>JOLIMONT WA, AUSTRALIA 6014 | Address | : 10 Hod Way Malaga WA Australia 6090 |
| E-mail | : anna.byrne@outbackecology.com | E-mail | : perth.enviro.services@alsglobal.com |
| Telephone | : +61 08 93888799 | Telephone | : +61-8-9209 7655 |
| Facsimile | : +61 08 93888633 | Facsimile | : +61-8-9209 7600 |
| Project | : SULP-SS-12001 | QC Level | : NEPM 1999 Schedule B(3) and ALS QCS3 requirement |
| Order number | : OES 3531 | | |
| C-O-C number | : ---- | Date Samples Received | : 04-DEC-2012 |
| Sampler | : VENTUREX REWSOURCES | Issue Date | : 11-DEC-2012 |
| Site | : ---- | | |
| | | No. of samples received | : 16 |
| Quote number | : EP-180-10 BQ | No. of samples analysed | : 16 |

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

*Signatories*

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

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Canhuang Ke | Metals Instrument Chemist | Perth Inorganics |
| Scott James | Laboratory Manager | Perth Inorganics |

## General Comments

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

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

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

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

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

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

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | SS01 0-20 | SS01 40-60 | SS02 0-20 | SS03 0-20 | SS03 40-60 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [04-DEC-2012] | [04-DEC-2012] | [04-DEC-2012] | [04-DEC-2012] | [04-DEC-2012] |
| Compound | CAS Number | LOR | Unit | EP1210107-001 | EP1210107-002 | EP1210107-003 | EP1210107-004 | EP1210107-005 |
| **EA055: Moisture Content** | | | | | | | | |
| Moisture Content (dried @ 103°C) | ---- | 1.0 | % | **2.0** | **5.8** | <1.0 | **1.4** | **5.2** |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| Arsenic | 7440-38-2 | 5 | mg/kg | <5 | <5 | <5 | <5 | <5 |
| Cadmium | 7440-43-9 | 1 | mg/kg | <1 | **1** | <1 | <1 | <1 |
| Chromium | 7440-47-3 | 2 | mg/kg | **72** | **56** | **36** | **41** | **15** |
| Copper | 7440-50-8 | 5 | mg/kg | **35** | **24** | **12** | **19** | **10** |
| Lead | 7439-92-1 | 5 | mg/kg | **8** | **9** | **6** | **10** | **7** |
| Nickel | 7440-02-0 | 2 | mg/kg | **66** | **52** | **11** | **30** | **16** |
| Zinc | 7440-66-6 | 5 | mg/kg | **110** | **110** | **19** | **73** | **63** |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | SS04 0-20 | SS05 0-20 | SS05 40-60 | SS05 100-120 | SS06 0-20 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [04-DEC-2012] | 04-DEC-2012 09:00 | [04-DEC-2012] | [04-DEC-2012] | [04-DEC-2012] |
| Compound | CAS Number | LOR | Unit | EP1210107-006 | EP1210107-007 | EP1210107-008 | EP1210107-009 | EP1210107-010 |
| **EA055: Moisture Content** | | | | | | | | |
| Moisture Content (dried @ 103°C) | ---- | 1.0 | % | 4.3 | 2.6 | 4.6 | 7.6 | 4.4 |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| Arsenic | 7440-38-2 | 5 | mg/kg | <5 | <5 | <5 | <5 | <5 |
| Cadmium | 7440-43-9 | 1 | mg/kg | 2 | 1 | <1 | <1 | <1 |
| Chromium | 7440-47-3 | 2 | mg/kg | 528 | 131 | 88 | 76 | 168 |
| Copper | 7440-50-8 | 5 | mg/kg | 383 | 119 | 110 | 106 | 85 |
| Lead | 7439-92-1 | 5 | mg/kg | 18 | 12 | 7 | 7 | 15 |
| Nickel | 7440-02-0 | 2 | mg/kg | 141 | 65 | 39 | 33 | 174 |
| Zinc | 7440-66-6 | 5 | mg/kg | 172 | 260 | 59 | 59 | 126 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | SS06 40-60 | SS07 0-5 | SS08 0-5 | SS09 0-5 | SS10 0-5 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [04-DEC-2012] | [04-DEC-2012] | [04-DEC-2012] | [04-DEC-2012] | [04-DEC-2012] |
| Compound | CAS Number | LOR | Unit | EP1210107-011 | EP1210107-012 | EP1210107-013 | EP1210107-014 | EP1210107-015 |
| **EA055: Moisture Content** | | | | | | | | |
| Moisture Content (dried @ 103°C) | ---- | 1.0 | % | **6.9** | <1.0 | **1.6** | **1.1** | **1.3** |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| Arsenic | 7440-38-2 | 5 | mg/kg | <5 | <5 | <5 | <5 | <5 |
| Cadmium | 7440-43-9 | 1 | mg/kg | <1 | <1 | <1 | <1 | <1 |
| Chromium | 7440-47-3 | 2 | mg/kg | **245** | **18** | **29** | **26** | **17** |
| Copper | 7440-50-8 | 5 | mg/kg | **104** | **41** | **13** | **16** | **6** |
| Lead | 7439-92-1 | 5 | mg/kg | **11** | **5** | **5** | **6** | <5 |
| Nickel | 7440-02-0 | 2 | mg/kg | **240** | **12** | **12** | **9** | **7** |
| Zinc | 7440-66-6 | 5 | mg/kg | **110** | **71** | **26** | **18** | **17** |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |

## Analytical Results

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

| | | | Client sample ID | **SS11 0-5** | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [04-DEC-2012] | ---- | ---- | ---- | ---- |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **EP1210107-016** | **----** | **----** | **----** | **----** |
| **EA055: Moisture Content** | | | | | | | | |
| **Moisture Content (dried @ 103°C)** | ---- | 1.0 | % | <1.0 | ---- | ---- | ---- | ---- |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| **Arsenic** | 7440-38-2 | 5 | mg/kg | <5 | ---- | ---- | ---- | ---- |
| **Cadmium** | 7440-43-9 | 1 | mg/kg | <1 | ---- | ---- | ---- | ---- |
| **Chromium** | 7440-47-3 | 2 | mg/kg | **20** | ---- | ---- | ---- | ---- |
| **Copper** | 7440-50-8 | 5 | mg/kg | **10** | ---- | ---- | ---- | ---- |
| **Lead** | 7439-92-1 | 5 | mg/kg | <5 | ---- | ---- | ---- | ---- |
| **Nickel** | 7440-02-0 | 2 | mg/kg | **7** | ---- | ---- | ---- | ---- |
| **Zinc** | 7440-66-6 | 5 | mg/kg | **15** | ---- | ---- | ---- | ---- |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.1 | mg/kg | <0.1 | ---- | ---- | ---- | ---- |

Environmental Division

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **EP1301249** | Page | : 1 of 4 |
| Client | : **OUTBACK ECOLOGY SERVICES** | Laboratory | : Environmental Division Perth |
| Contact | : ANNE BYRNE | Contact | : Scott James |
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| Project | : SULP-SS-13001 | QC Level | : NEPM 1999 Schedule B(3) and ALS QCS3 requirement |
| Order number | : OES 3634 | | |
| C-O-C number | : ---- | Date Samples Received | : 20-FEB-2013 |
| Sampler | : ---- | Issue Date | : 27-FEB-2013 |
| Site | : ---- | | |
| | | No. of samples received | : 9 |
| Quote number | : EP-180-10 BQ | No. of samples analysed | : 9 |

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

*Signatories*

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

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Scott James | Laboratory Manager | Perth Inorganics |
| Scott James | Laboratory Manager | Perth Inorganics |

## General Comments

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

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

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

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

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

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

- **EG005T: Poor matrix spike recovery due to sample heterogeneity. Confirmed by re-extraction and re-analysis.**

## *Analytical Results*

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

| Compound | CAS Number | LOR | Unit | Site 12 | Site 13 | Site 14 | Site 15 | Site 16 |
|---|---|---|---|---|---|---|---|---|
| | | | *Client sampling date / time* | [20-FEB-2013] | [20-FEB-2013] | [20-FEB-2013] | [20-FEB-2013] | [20-FEB-2013] |
| | | | | **EP1301249-001** | **EP1301249-002** | **EP1301249-003** | **EP1301249-004** | **EP1301249-005** |
| **EA055: Moisture Content** | | | | | | | | |
| **Moisture Content (dried @ 103°C)** | ---- | 1.0 | % | **2.3** | **3.0** | **6.9** | **3.8** | **3.8** |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| **Arsenic** | 7440-38-2 | 5 | mg/kg | <5 | <5 | **7** | <5 | <5 |
| **Cadmium** | 7440-43-9 | 1 | mg/kg | <1 | <1 | <1 | <1 | <1 |
| **Chromium** | 7440-47-3 | 2 | mg/kg | **128** | **211** | **454** | **266** | **279** |
| **Copper** | 7440-50-8 | 5 | mg/kg | **20** | **45** | **56** | **42** | **40** |
| **Lead** | 7439-92-1 | 5 | mg/kg | **6** | <5 | <5 | <5 | <5 |
| **Nickel** | 7440-02-0 | 2 | mg/kg | **52** | **171** | **243** | **195** | **190** |
| **Zinc** | 7440-66-6 | 5 | mg/kg | **42** | **129** | **127** | **130** | **142** |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | Site 17 | Site 18 | Site 19 | Site 20 | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [20-FEB-2013] | [20-FEB-2013] | [20-FEB-2013] | [20-FEB-2013] | ---- |
| Compound | CAS Number | LOR | Unit | EP1301249-006 | EP1301249-007 | EP1301249-008 | EP1301249-009 | ---- |
| **EA055: Moisture Content** | | | | | | | | |
| Moisture Content (dried @ 103°C) | ---- | 1.0 | % | 3.5 | 1.9 | 3.7 | 3.6 | ---- |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| Arsenic | 7440-38-2 | 5 | mg/kg | <5 | <5 | <5 | <5 | ---- |
| Cadmium | 7440-43-9 | 1 | mg/kg | <1 | <1 | <1 | <1 | ---- |
| Chromium | 7440-47-3 | 2 | mg/kg | 399 | 127 | 137 | 106 | ---- |
| Copper | 7440-50-8 | 5 | mg/kg | 45 | 50 | 65 | 30 | ---- |
| Lead | 7439-92-1 | 5 | mg/kg | <5 | 9 | 6 | 6 | ---- |
| Nickel | 7440-02-0 | 2 | mg/kg | 192 | 60 | 112 | 51 | ---- |
| Zinc | 7440-66-6 | 5 | mg/kg | 54 | 50 | 97 | 34 | ---- |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | ---- |

# Appendix 3: Closure Risk Assessment

# Risk Assessment Framework

## Consequence Rating

| Impact On | Insignificant | Minor | Moderate | Major | Catastrophic |
|---|---|---|---|---|---|
| **Project Schedule** | < 1 Month | > 3 months | > 6 months | > 1 year | > 5 years |
| **Project Cost** | < $50,000 | $50,000 - $100,000 | $500,000 - $1,000,000 | >$1M - $10M | >$10 M |
| **Safety** | First Aid<br>Minor Treatment | Medical Treatment<br>Temporary Injury | Hospitalisation<br>Permanent Injury | Single Fatality<br>Loss of quality of life | Multiple Fatalities<br>Ultimately fatal |
| **Environment** | Localised Degradation (within footprint)<br>< 1 year recovery time | Site Wide Degradation (within lease)<br>< 5 years recovery time | Severe Degradation (beyond mine lease)<br>< 10 years recovery time | Major Degradation (regional)<br>Decades to recover | Catastrophic Degradation (inter regional)<br>Centuries to recover |
| **Regulatory Compliance** | Annual Incident Report | Official Censure | Fines | Prosecution | Business Closure |
| **Community Relations** | Local awareness | Local Press | State Press | National Press | International Press |
| **Company Reputation** | Superintendent | Line Manager | General Management | Managing Director | Board/Corporate Management |

## Likelihood Rating

| Likelihood | Probability that the stated consequence will occur |
|---|---|
| Almost Certain | Incident is very likely to occur on this project, possibly several times (>1 in 2 chance of occurring) |
| Likely to happen | Incident is likely to occur on this project (1 in 2 chance of occurring) |
| Possible | Incident has occurred on a similar project (1 in 10 chance of occurring) |
| Unlikely | Given current practices and procedures, this incident is unlikely to occur on this project (1 in 100 chance of occurring). |
| Rare | Highly unlikely to occur on this project (1 in 1000 chance of occurring) |

## Risk Rating

| RISK RANKING MATRIX | | | | | | | |
|---|---|---|---|---|---|---|---|
| | High | | Likelihood Scale (LS) | | | | |
| | Medium | | Almost Certain | Likely | Possible | Unlikely | Rare |
| | Low | Level | 10 | 8 | 6 | 4 | 3 |
| Consequence Scale (LS) | Catastrophic | 10 | 100 | 80 | 60 | 40 | 30 |
| | Major | 8 | 80 | 64 | 48 | 32 | 24 |
| | Moderate | 6 | 60 | 48 | 36 | 24 | 18 |
| | Minor | 4 | 40 | 32 | 24 | 16 | 12 |
| | Insignificant | 2 | 20 | 16 | 12 | 8 | 6 |

| Risk / Hazard | Current Status/ Controls/ Mitigations | Inherent | | | Proposed Additional / Future Controls | Residual | | |
|---|---|---|---|---|---|---|---|---|
| | | Cons. | Prob. | Risk | | Cons. | Prob. | Risk |
| **Damage to reputation because concerns of stakeholders are not addressed.** | | | | | | | | |
| Significant stakeholder concerns not identified, or misunderstood, leading to failure to meet expectations, loss of trust and reputation, and potential regulatory/civil action. | • Extensive stakeholder engagement and consultation completed to date as part of project approvals and Native Title Mining Agreement negotiation.<br>• Conceptual MCP for project incorporates stakeholder engagement and consultation program. | Mod | Poss | 36 Med | • Maintain and refine stakeholder engagement program over life of operations.<br>• Maintain register and records of stakeholder consultation over life of operations.<br>• Invite all relevant stakeholders to review and comment on periodic MCP revisions. | Mod | Unlik | 24 Low |
| **Failure to meet closure obligations and completion criteria and resultant inability to achieve timely Mining Lease relinquishment** | | | | | | | | |
| Obligations not identified, misunderstood, or change over life of project, leading to noncompliance. | • Closure obligations and criteria incorporated into conceptual MCP.<br>• Ongoing stakeholder engagement and consultation to refine criteria during future MCP up-dates | Mod | Poss | 36 Med | • Regular review of relevant legislation and update obligations register and MCP as part of operations.<br>• Implement stakeholder engagement program over life of operations. | Mod | Unlik | 24 Low |
| Obligations prove impracticable, leading to noncompliance / breach of agreement. | • Current closure obligations consistent with industry practice, but yet to be demonstrated practicable for this project.<br>• Conceptual MCP incorporates studies intended to determine practicability of rehabilitation objectives and set appropriate criteria. | Major | Poss | 48 Med | • Complete studies to determine practicability of rehabilitation objectives and set appropriate criteria.<br>• Where obligations, objectives or criteria appear impracticable, negotiate alternatives through stakeholder engagement and consultation.<br>• Maintain appropriate risk provisions where uncertainty remains over closure criteria. | Mod | Unlik | 24 Low |
| Decommissioning and rehabilitation works not completed to specification, leading to failures to meet closure obligations or objectives, and need for remedial works. | • Decommissioning and rehabilitation designs/strategies to have technical peer review.<br>• Engineering designs to meet Industry closure standards and design specifications. | Major | Poss | 48 Med | • Include clear specifications based on approved MCP in tenders and contracts for decommissioning and rehabilitation works.<br>• Closely supervise rehabilitation works and survey to confirm conformance to design before acceptance by Venturex. | Major | Unlik | 32 Med |
| **Premature closure of the mine resulting in financial shortfall or insufficient material to meet closure obligations** | | | | | | | | |
| Closure without adequate liquidity to complete outstanding closure obligations. | • Closure costs estimated for net present value and cashflow forecasts as part of project feasibility studies.<br>• Market volatility and other financial risks priced into project feasibility and present value. | Major | Poss | 48 Med | • Review closure obligations and associated costs every year; make and disclose adequate provisions in line with accounting standards and ASX rules.<br>• Where practicable, make provisions for early closure e.g. mining overburden for rehabilitation in event of early closure.<br>• Resource modelling and geotechnical assessment carried out to reduce likelihood of early closure due to invalid resource model or pit failure. | Major | Unlik | 32 Med |
| Premature closure of the mine, potentially leading to a shortfall of Non Acid Forming (NAF) oxide mine waste material for covering the waste rock dump PAF cells and tailings material. | • Growth medium resources identified within project footprint; plan prepared for harvesting and stockpiling as part of project development.<br>• Current mine plan material balance indicates that overall volumes of NAF material greatly exceed that of PAF material and should meet all reclamation needs.<br>• Actual risk relates to availability at specific periods during the scheduled mining operation should mining cease for any reason at a stage when the PAF waste rock stream temporarily exceeds the NAF supply. This risk has been recognised by the mine planners and mine waste scheduling was adjusted accordingly. As shown in Section 10.2.3 of MCP, cumulative volumes of NAF waste rock are far in excess of cumulative volumes of PAF waste rock throughout the WRD construction period. | Major | Unlik | 32 | • The mining scheduling will be checked annually to ensure that the stockpile of NAF mine waste material is always in excess of the closure design requirements.<br>• The waste rock dump PAF encapsulation area is within the long term mine pit dewatering cone of depression. | Mod | Unlik | 24 Low |
| **Insufficient mine closure planning resulting in underestimation of possible closure costs and an inappropriate Closure Provision** | | | | | | | | |
| Underestimation of closure costs leading to inadequate funds to complete closure activities to the satisfaction of DMIRS. | • Venturex financial risk management includes retaining enough liquidity to meet closure obligations under normal and stressed conditions without incurring unacceptable losses.<br>• Costing methodology considers factors influencing closure costs, including current rates for labour and equipment. | Mod | Poss | 36 Med | • Venturex will maintain financial provisions (liabilities of uncertain timing or amount) sufficient to cover incurred closure obligations, in a manner consistent with Australian Accounting Standards Board (AASB) Standard 137 *Provisions, Contingent Liabilities and Contingent Assets.*<br>• Engage decommissioning and earthworks / mining engineers to assist with refining closure cost estimates as site approaches closure. | Mod | Unlik | 24 Low |
| Rehabilitation materials double-handled or inefficiently moved, leading to unnecessary cost. | • Site reclamation materials balance incorporated in MCP and scheduled to be regularly up-dated based on changing Life of Mine (LOM) Plan | Mod | Poss | 36 Med | • Implement plan to harvest and stockpile growth medium as part of project development; identify best stockpile locations / arrangements to minimise handling and haulage costs. | Mod | Unlik | 24 Low |

| Risk / Hazard | Current Status/ Controls/ Mitigations | Inherent | | | Proposed Additional / Future Controls | Residual | | |
|---|---|---|---|---|---|---|---|---|
| | | Cons. | Prob. | Risk | | Cons. | Prob. | Risk |
| Assets demolished, or parts or materials disposed of that could have been sold or taken, leading to unnecessary cost. | • Major plant components may have significant residual value to another operation at closure.<br>• Other facilities including fuel tanks, generators and demountable buildings (if not leased) may have residual value to third party at closure.<br>• Scrap from plant and other structures or other recyclables may have enough value to at least cover cost of collection. | Mod | Poss | 36 Med | • Maintain asset register over life of operations.<br>• Progressively send parts and materials off site for salvage, scrap or recycling over life of operations, where economic to do so.<br>• Engage industrial/ mining auctioneers / scrap merchants / recyclers to visit operations as closure approaches, to identify items of value and potential buyers.<br>• Plan decommissioning to carefully salvage parts of value before demolition begins.<br>• Set aside parts, scrap, and other recyclables for collection as part of demolition works, if cost-neutral compared to disposal on site. | Mod | Unlik | 24 Low |
| Ineffective safety measures during closure operations and post-closure resulting in injury or death of workers, general public or livestock. | | | | | | | | |
| Occupational Health and Safety (OHS) risks for decommissioning and rehabilitation works not properly identified, leading to occupational illness or injury. | • Project Management Plan (PMP) being developed for project under Mine Safety and Inspection Regulations (MSIR), including risk assessment for all works to be carried out on site.<br>• Rehabilitation earthworks generally similar to mining. | Major | Poss | 48 Med | • Review and update OH&S risk assessment in PMP to address decommissioning and rehabilitation works.<br>• Implement all controls for decommissioning and rehabilitation works as identified in PMP.<br>• Conduct Job Hazard Analysis (JHA) on site before commencing decommissioning and rehabilitation tasks. | Mod | Poss | 36 Med |
| Public or livestock enter site leading to accident causing injury or death. | • Remote site, off main routes. Incidental visitation by public is unlikely.<br>• Mining area de-stocked and fenced ahead of mine construction and operations. | Cat | Unlik | 40 Med | • Set up and maintain temporary fences and warning signs around hazardous areas and across access roads during closure works.<br>• Isolate and make safe plant and equipment.<br>• Construct and maintain perimeter fence. | Cat | Unlik | 40 Med |
| Public enter into hazardous areas after closure, leading to accident causing injury or death. | • Remote site, off main routes. Incidental visitation by public is unlikely.<br>• Expected return to pastoral grazing / unallocated crown land after closure. | Cat | Unlik | 40 Med | • Dismantle or demolish hazardous structures at closure.<br>• Remove or safely bury hazardous or contaminated materials at closure.<br>• Determine long-term zone of potential subsidence or instability around mine voids.<br>• Place abandonment bunds around voids and areas of potential subsidence / instability at closure.<br>• Push waste landforms batters, sides of borrow pits, etc. down to safe, stable angle, or bund off.<br>• Install signs deterring access and warning of hazards at closure.<br>• Rehabilitate site access roads and close off with substantial permanent bunds at closure. | Cat | Rare | 30 Med |
| Landform instability resulting in loss of containment from the TSF and to a lesser extent the WRD. | | | | | | | | |
| Water pooling or discharging from landform upper surface, leading to erosion and discharge of sediments/tailings into surrounding environment. | • NAF material is expected to be mined in sufficient quantities to adequately cover PAF material.<br>• Mine waste landform closure designs will be focused on achieving long term geotechnical stability of outer batters as well as on internal terraced (flats) areas.<br>• Valley fill designs for WRD and TSF mean that the robust, erosion resistant valley walls form part of outer batters for each structure. | Mod | Poss | 36 Med | • Closure strategies will be based on engineering and scientific proven designs and specifications.<br>• Long term geotechnical stability of all mine workings will be assessed by suitably qualified professional staff during the closure phase to ensure that any potential zones of instability are identified and precautionary action can be taken. This could entail buttressing, backfilling, slope re-profiling or isolation by means of bunding and appropriate signage.<br>• Geotechnical stability monitoring will continue throughout the post closure monitoring phase. | Mod | Unlik | 24 Low |

| Risk / Hazard | Current Status/ Controls/ Mitigations | Inherent | | | Proposed Additional / Future Controls | Residual | | |
|---|---|---|---|---|---|---|---|---|
| | | Cons. | Prob. | Risk | | Cons. | Prob. | Risk |
| Ineffective drainage control (seepage and surface runoff) resulting in discharge of contaminated water | | | | | | | | |
| Post-closure, surface water runoff could change surface water quality via:<br>• Reduced groundwater discharge rates created by surface water diversion/capture. A permanently low water table will reduce the acid and solute loads currently reporting to Sulphur Springs Creek.<br>• Changes in pit lake water quality over time due to:<br>– Accumulation of solute loads from groundwater inflows and surface water runoff – including run-off and reactions with materials exposed in the pit walls.<br>– Acid balance as a result of mixing between acid-generating and acid-neutralising components of water inflows and wall rock materials.<br>– Evapo-concentration of solutes.<br>• Reduced surface water quality due to discharge of contaminants and increased turbidity and sedimentation.<br>The quality of surface water runoff from the rehabilitated WRD and TSF landforms are expected to improve following closure. Initially, surface water will be affected by runoff and superficial erosion from the disturbed surface, but this will stabilise once revegetation has established. | • Specialist baseline hydrological studies<br>• Water Management Plan developed to inform design of surface water diversions. | Maj | Poss | 48 Med | • All drainage from and around mine waste landforms and the mine pit will need to be reassessed at the time of closure to ensure that drainage control structures are adequate for PMP and PMF conditions.<br>• Potential sources of sedimentation and contamination will be removed and remediated as required. The most likely source of sedimentation during operations will be a large stockpile of growth medium, which will be reused on site as part of closure activities.<br>• Where required, water will be drained into the pit to capture contaminants and/or support the pit lake water balance and level.<br>• Prior to closure, the proponent will:<br>– Review the pit catchment diversions and revise the pit lake water model.<br>– Review the need to retain contaminants and sediments from WRD and TSF seepage and runoff.<br>– Refine the pit lake model as part of closure planning. This model will inform surface water design and management measures required to maintain the pit lake as a hydraulic sink within the local water table. As a result, solutes within the mine void are unlikely to migrate a significant distance from the pit void (AECOM 2018b).<br>– Closure of the WRD will incorporate an engineered cover, designed to minimise ingress of air (oxygen) and water to the encapsulated PAF area, therefore reducing the potential to generate AMD.<br>– Closure of the TSF will also incorporate an engineered cover to minimise ingress of oxygen and water to the tailings mass and therefore reduce the potential to generate AMD. | Maj | Unlik | 32 Med |
| Ineffective pit sub-catchment modifications resulting in pit lake seepage | | | | | | | | |
| Post closure the project has potential to contaminate surface water through seepage into the groundwater, which recharges local creeks.<br><br>Seepage from the TSF is predicted to percolate vertically to the water table where it will mix with local groundwater. This mix will gradually migrate to the pit lake. The pit lake is expected to remain a groundwater sink under the majority of rainfall scenarios | • No nearby users of groundwater resources.<br>• TSF location, design and operating strategy to minimise potential for AMD and confine seepage to the pit lake catchment.<br>• Water Management Plan to mitigate any impacts from seepage.<br>• Proposed PAF cells in the WRD will be upstream of the open pit. Seepage from these structures will be captured in the pit lake catchment. | Maj | Poss | 48 Med | • Monitor groundwater around TSF over life of operations to delineate and quantify any seepage impacts.<br>• Final design criteria of the TSF will be informed by the results of water monitoring during operations.<br>• Designs of WRD will consider management of inflows to the pit in order to minimise groundwater that may contribute to Sulphur Springs baseflow.<br>• Conduct studies over life of operations to demonstrate effectiveness of proposed tailings cover.<br>• Monitor groundwater after closure, to confirm that any seepage impacts from operations are restricted to the pit lake catchment. | Maj | Unlik | 32 Med |
| Ineffective pit sub-catchment modifications resulting in pit lake overtopping | | | | | | | | |
| After closure the pit water level is expected to rise slowly and could eventually overtop if all catchment runoff were to discharge into the pit post closure. This may result in surface water contamination from overtopping of the pit lake. | • Preparation of a Mine Closure Plan consistent with Department of Mines and Petroleum and EPA *Guidelines for Preparing Mine Closure Plans* (2015) which addresses the development of completion criteria to maintain the quality of land and soils and surface water so that environmental values are maintained post closure.<br>• Mine pit lake water balance modelling | Maj | Poss | 48 Med | • Drainage strategies being influenced by findings from the AECOM (2020b) assessment of possible rainfall and upstream catchment scenarios in a pit water balance study<br>• Implementation of an operational surface and groundwater management plan, incorporating monitoring of groundwater levels and quality to identify any changes beyond those predicted and trigger management actions.<br>• Further hydrogeological studies to confirm hydraulic properties of geological faults associated with the pit and the presence of a critical stage-height of the pit lake for seepage containment.<br>• Further refinement of the pit lake model and water balance study as part of closure planning. This model will inform surface water design and management measures required to ensure the pit lake maintains a hydraulic sink within the local water table. As a result, solutes within the mine void are unlikely to migrate a significant distance from the pit void. | Maj | Unlik | 32 Med |
| Rehabilitate disturbed areas to support, as far as practicable, self-sustaining vegetation and habitats similar to surrounding undisturbed areas. | | | | | | | | |

| Risk / Hazard | Current Status/ Controls/ Mitigations | Inherent | | | Proposed Additional / Future Controls | Residual | | |
|---|---|---|---|---|---|---|---|---|
| | | Cons. | Prob. | Risk | | Cons. | Prob. | Risk |
| Inadequate growth medium resources available at closure leading to need to mine additional growth medium to support revegetation objectives | • Baseline soil characterisation studies suggest sufficient volumes of material will be present on site. Further characterisation studies will be done prior to commencement of operations to assess whether these materials are suitable for closure purposes in their current form, or if supplements/treatments will be required.<br>• Growth medium resources identified within project footprint; plan prepared for harvesting and stockpiling as part of project development. | Mod | Poss | 32 Med | • Implement plan to harvest and stockpile growth medium as part of project development.<br>• Protect growth medium stockpiles over life of operations. | Mod | Poss | 32 Med |
| Topsoil and growth medium does not contain adequate seedbank at closure, leading to poor revegetation and/or need to collect supplementary seed. | • Obligations under NTMA and tenement conditions to stockpile topsoil separately to preserve seedbank.<br>• Obligation under NTMA to seed growth medium stockpiles as soon as possible with locally collected native seed to boost seedbank in stockpiles by end of mine life. | Minor | Poss | 24 Low | • Strip vegetation from areas to be disturbed, and stockpile for rehabilitation use.<br>• Protect vegetation and topsoil stockpiles over life of operations, from erosion, dust, disturbance, saline water, contamination, etc.; arranges stockpiles to avoid surface water flows.<br>• Strip topsoil to isolate seedbank, and stockpile to no more than 2 m thick to preserve seedbank.<br>• Spread native seed mix over growth medium stockpiles as soon as possible to establish seedbank.<br>• Collect and store local native seed over life of operations for supplementary seeding of rehabilitated areas if required. | Minor | Unlik | 16 Low |
| Inability to relinquish the site with no outstanding legal or social liability | | | | | | | | |
| Insufficient evidence that closure criteria will be met in the long term, preventing or delaying tenement relinquishment. | • The closure criteria recognise that some closure processes such as landform evolution may take hundreds of years and are impractical to monitor to completion. | Mod | Poss | 36 Med | • Conduct studies over the life of operations to determine practicable criteria, commensurate with the degree of associated risk.<br>• Conduct revegetation trials over as many years as possible to assess performance in a variety of rainfall scenarios.<br>• Collect sufficient data and conduct sufficient modelling for long-term processes to have confidence in predictions.<br>• Design and conduct post-closure monitoring that aligns with and can demonstrate sufficient progress toward agreed closure criteria within a reasonable time.<br>• Ensure adequate provision made for pre-closure studies and post-closure monitoring.<br>• Maintain stakeholder engagement over life of operations to renegotiate practicable closure criteria where appropriate.<br>• Maintain appropriate risk provisions where uncertainty remains over ability to meet closure criteria. | Mod | Unlik | 24 Low |
| Assets / infrastructure handed over without full transfer of all associated liabilities, leading to unexpected costs or legal actions against Venturex. | • Cost of any ongoing maintenance of infrastructure identified for transfer post closure will be covered by a Closure Fund, to be used in perpetuity post completion of closure works, to provide for long term monitoring and maintenance of such infrastructure. The mechanism for establishment of the fund, size of the provision and administration of the fund will be discussed with key stakeholders prior to commencement of operations, with funds to be provided after completion of construction of the proposed pit water diversion tunnel/s. | Mod | Poss | 36 Med | • Engage legal consultants to assist with legal framework and binding agreements for transfer of liability, as and when opportunities for transfer are identified.<br>• Conduct technical and legal risk assessment for handover of assets/ infrastructure to ensure that all potential risks are identified and liabilities (including financial, community, safety, environment and monitoring) are clearly transferred.<br>• Ensure that transfer agreements clearly set out preconditions and responsibilities for handover (e.g., works to be completed or modifications made, transfer of licences, etc.) | Mod | Unlik | 24 Low |
| Contaminated sites remain unidentified or unresolved at closure, leading to ongoing liability under CS Act. | • Greenfields site with no known pre-existing contamination.<br>• Minor spills of hydrocarbons and process reagents likely to occur over life of project, with substantial cumulative effect if not well managed.<br>• Investigation and remediation of some sites may be impracticable until after decommissioning, due to buried services, ongoing operations, etc.<br>• Remote site with pastoral land use, no likely future use such as residential or recreational that may require higher standards of remediation. | Mod | Likely | 48 Med | • Implement measures to avoid creating a legacy of contaminated sites during life of operations, including spill prevention, cleanup, remediation and validation.<br>• Report and investigate contamination according to CS guidelines.<br>• Investigate and remediate contaminated sites progressively where practical and necessary, leave others till final closure if demonstrably safe to do so.<br>• Determine closure criteria for contamination in line with CS guidelines and expected future land use. | Mod | Unlik | 24 Low |

# Appendix 4: TSF Preliminary Concept Design (KPC 2020)

## MEMORANDUM

| | | | |
|---|---|---|---|
| **To:** | **Venturex Resources Pty Ltd** | **Date:** | 22 January 2020 |
| **Attn:** | Piers Goodman | **Our Ref:** | PE20-00063 |
| | | **KP File Ref.:** | PE801-00300/12-A sjs M20002 |
| **cc:** | Brad Walker | **From:** | Simon Smith |

**RE: SULPHUR SPRINGS ZINC-COPPER PROJECT – TAILINGS STORAGE FACILITY PRELIMINARY CONCEPT DESIGN REV. 1**

# 1. INTRODUCTION

A number of options for management of the tailings and excess de-watering water streams have been considered by different proponents during the course of the project history. The Definitive Feasibility Study (DFS) (Ref. 1) tailings storage facility (TSF) is located in the valley north of the plant infrastructure and was designed to store 8.48 Mt of tailings and 5.31 GL of excess de-watering water over the life of the project.

Following meetings with the Environmental Protection Authority (EPA) and the Department of Mines, Industry Regulation and Safety (DMIRS) during the last quarter of 2019, Venturex engaged Knight Piésold Pty Ltd (KP) to carry out a concept design for an alternative TSF location occupying the catchment to the south-east of the proposed open pit.

This memorandum presents a preliminary concept design for the alternative TSF location and supersedes memorandum PE20-0042 dated 17th January 2020.

# 2. TSF CONCEPT DESIGN

## 2.1 GENERAL

The project site lies within three surface water catchments, Sulphur Springs Creek (SSC), Minnieritchie Creek (MRC), and Six Mile Creek (SMC). Each of these catchments were de-lineated into sub-catchments (as part of previous phases of work), SSC1 to 8, MRC1 to 7, and SMC1 to 6. In addition, the catchments contributing directly to the open pit, Pit Shell Catchments PSC1 to 6, were de-lineated. The proposed open pit intersects the drainage course of Sulphur Springs Creek and is situated at the foot of the Sulphur Springs Creek catchment (PSC5).

The DFS infrastructure design incorporated a pit diversion dam directly to the south-east of the pit shell to intercept rainfall run-off from the upstream catchment as a means to reduce the risk of flooding the open pit workings during operations. The alternative TSF concept uses the PSC5 catchment as a tailings storage facility, in effect replacing the pit diversion dam and the requirement to actively manage the catchment diversion post-closure.

## 2.2 TSF CONSEQUENCE/HAZARD ASSESSMENT

A significant failure of any of the TSF embankments would result in a release of tailings and/or water, though the extent and magnitude of the release would depend on the location of the breach, its size and the cause. For the alternative TSF location a breach of the main embankment would result in a tailings flow slide into the open pit whilst a breach of the southern saddle dam (based on the assessment carried out for the DFS) would likely result in a flow slide predominantly to the east into the Minnieritchie Creek catchment and then flowing to the north.

The hazard rating of a facility is derived by considering the potential impacts of a significant embankment breach and resulting release of tailings slurry in terms of safety, environmental and economic factors. The assessment presented herein is an initial assessment only and will need to be developed in more detail during subsequent design phases to confirm the assigned hazard rating.

In accordance with the DMIRS Code of Practice, “Tailings storage facilities in Western Australia” (Ref. 2), the TSF is classified as “Category 1” regardless of its hazard rating, on the basis that the facility will reach a final embankment height in excess of 15 m. This categorisation requires specific supporting documentation, design approach, construction control, operating procedures and rehabilitation approach to ensure it is safe, stable, erosion-resistant and non-polluting throughout its lifecycle.

A high level assessment of consequence category has been carried out with reference to the ANCOLD “Guidelines on the Consequence Categories for Dams” (Ref. 3). The severity of damage and loss resulting from the dam failure together with the assessed population at risk and probable loss of life are used to determine the consequence category. The severity level impact is assessed to be Major due to a potentially Severe to Crippling impact on the business as a result of a dam failure into the open pit. In addition the Population at Risk (PAR) is estimated to be >10-100 based on an estimated 20-35 persons working in the open pit at any time. It is understood that the access portal to the underground workings will originate in the process plant valley and therefore the PAR will be limited to those personnel working in the open pit up to cessation of open pit mining in Year 5.

A summary of the consequence/hazard assessment and derivation of the facility consequence categories is presented in Table 2.1. On the basis of the assessment provided the TSF is rated as a ‘High B’ consequence category facility. The design criteria applicable to this category are drawn from the ANCOLD “Guidelines on Tailings Dams” and are summarised in Table 2.2.

**Table 2.1:** Assessment of consequence category (PAR) (ANCOLD 2019)

| Embankment | Population at Risk (PAR) | Severity of Damage and Loss | | | |
|---|---|---|---|---|---|
| | | Minor | Medium | Major | Catastrophic |
| North Embankment | ≥10 < 100 | High C | High C | **High B** | High A |

**Table 2.2:** ANCOLD design criteria summary

| Guideline Requirement | Description of requirements – High B* | Guideline Reference |
|---|---|---|
| Extreme storm storage | 1 in 1,000 year AEP 72 hour duration storm with no release, evaporation or decant. | ANCOLD 2019 Table 4 |
| Contingency freeboard | Wave run-up associated with a 1:50 AEP wind velocity and an additional freeboard of 0.5 m | ANCOLD 2019 Table 5 |
| Spillway capacity | 1 in 100,000 year Annual Exceedance Probability (AEP) design flood with freeboard allowance to suit wave run-up for 1:10 AEP wind velocity or PMF | ANCOLD 2019 Table 6 |
| Design earthquake loading | OBE 1 in 1,000 AEP<br>SEE 1 in 5,000 AEP<br>Post Closure MCE | ANCOLD 2019 Table 7 |
| Stability minimum factor of safety | Long term drained 1.5<br>Short term undrained<br>• Downstream 1.5<br>• Upstream 1.3<br>Post Seismic 1.0 – 1.2 | ANCOLD 2019 Table 8 |
| Dam safety/ inspection frequency | Comprehensive inspection by Dams Engineer and Specialist (where relevant) after first year of operation, then every 2 years Intermediate inspection by Dams Engineer annually.<br>Routine inspections – daily to 3 times per week by operations personnel/inspector. | ANCOLD 2019 Tables 9 and 10 |

*consequence category

## 3. DESIGN PARAMETERS

The total ore production from open cut and underground is 12.5 Mt. The proposed plant throughput rate is 1.25 Mtpa. Copper and Zinc transition ore will be processed for the first 2.5 years with proposed concentrate extraction of 7% and 12% respectively giving a tailings production rate ex plant of 1.135 Mtpa. Subsequently, fresh ore will be processed with proposed concentrate extraction of 18% giving a tailings production rate ex plant of 1.025 Mtpa for the remainder of the mine life. During the underground production phase some tailings, estimated as a total tailings tonnage of 0.21 Mt, may be used for mine backfill. However, this has not been confirmed and is disregarded for the purposes of the TSF design. The TSF design was based on the production data as detailed in Table 3.1. The design criteria and standards adopted for design of the TSF are presented in Table 3.2.

De-watering, mining, processing, and operation of the TSF will commence at different times and operate for different periods. Table 3.3 summarises the timing of each project component.

**Table 3.1:** TSF process design criteria

| DESIGN COMPONENT/VALUE | PERIOD | | TOTAL |
|---|---|---|---|
| PROCESSING DATA | Year 0 to 2.5 | Year 2.5 to 10 | |
| • Ore Production (Mt) | | | 12.5 |
| Copper/Zinc transition | 3.1 | - | 3.1 |
| Fresh | - | 9.4 | 9.4 |
| • Plant throughput (Mtpa) | 1.25 | 1.25 | |
| • Concentrate extraction (%) | 7-12 | 18 | |
| • Mine backfill (Mt) | 0 | 0.21^ | - |
| • Tailings production (Mtpa) | 1.135 | 1.025 | - |
| TSF | | | |
| Storage Capacity - Final (10.53 Mt of dry tails over 10 years) | 2.84 | 7.69 | 10.53 |
| - Starter (1.14 Mt of dry tails – 12 months capacity) | - | - | 1.14 |
| Production Rate (t/day of dry tails) | 3,110 | 2,808 | - |

^disregarded

**Table 3.2:** TSF design criteria

| | |
|---|---|
| PROJECT OPERATIONS | |
| Tailings Storage - Final<br>- Starter | • 10.53 Mt.<br>• 1.14 Mt. |
| Slurry Characteristics | • 50/55% solids by weight – Zinc/Copper transition ore.<br>• 60% solids by weight – Fresh ore.<br>• Slurry settled density – 1.9 – 2.0 t/m$^3$.<br>• Supernatant release – 50-60%.<br>• Potentially acid forming (PAF) tailings. |
| Fluid Management | • Partial basin drainage system drains by gravity to sump and is then pumped into the supernatant pond.<br>• Decant removal of supernatant solution via a pumping system and pressure pipeline back to the plant. |
| HYDRAULIC DESIGN | |
| TSF storm storage capacity | • 1:1,000 AEP, 72 hour flood |
| TSF emergency spillway | • PMF |
| EMBANKMENT STABILITY/EARTHQUAKE CRITERIA | |
| Earthquake Loading<br>- Operating Basis Earthquake (OBE)<br>- Safety Evaluation Earthquake (SEE) | <br>• 1 in 1,000 year ARI<br>• 1 in 5,000 year ARI |
| Stability Factors of Safety<br>- Long term drained<br>- Short term undrained (potential loss of containment)<br>- Short term undrained (no potential loss of containment)<br>- Post seismic | <br>• 1.5<br>• 1.5<br>• 1.3<br>• 1.0 - 1.2 |

**Table 3.2 (cont'd):** TSF design criteria

| FACILITY CONSTRUCTION AND OPERATION | |
|---|---|
| General | • Deposition from north and south embankments.<br>• Minimum tailings freeboard of 0.5 m.<br>• The supernatant pond will form towards the centre of the facility. Decant facilities will be provided at all stages to enable removal of water from the pond. |
| Construction | • Upstream cut-off trench and toe drain.<br>• Zoned starter embankment constructed from mine waste and/or local borrow, comprising an upstream low permeability zone and downstream structural zone.<br>• 10 m crest width. |
| Materials | • Remove unsuitable foundation soils from embankment footprint. Structural fill won from mine waste and/or local borrow.<br>• Low permeability material won from selected local borrow areas. |
| TAILINGS BASIN | |
| Basin Lining | • Imported soils, scarified, moisture conditioned and compacted to form a partial soil liner. |
| Basin Underdrainage | • Partial basin underdrainage system comprising main collector drains along part of the basin spine. |

**Table 3.3:** Scheduling of operational components

| Month | De-watering | Mining | Process | TSF |
|---|---|---|---|---|
| 1 | | Mining starts – pre-strip for construction | | |
| 12 | De-watering commences | | Process plant commissioned | TSF commissioned |
| 13 | | | | TSF fully operational |
| 132 | De-watering ends | Mining ceases | Process plant ceases operation | TSF ceases operation |

# 4. TAILINGS CHARACTERISTICS

## 4.1 PREVIOUS TESTING

### 4.1.1 Report Review

A number of historical reports were reviewed during the DFS to establish the scope and findings of previous tailings testing:

1. Bankable Feasibility Study Report, Sulphur Springs Project, 06641103-R01-Rev F, Golder Associates, November 2006;
2. Sulphur Springs Bankable Feasibility Study, Tailings Storage Facility, Design Document, P7209.01-AC Design Rev 2, Coffey Geosciences, November 2006; and
3. Panorama Project, Geochemical Characterisation of Process-Tailings Sample (Static Testwork), Implications for Process-Tailings Management, Graeme Campbell and Associates, April 2002;

A review of these reports indicated that:

- tailings test work was performed in 2002;
- the TSF design adopted a settled density of 1.5 t/m$^3$;
- the TSF design adopted a tailings permeability of 1 x 10$^{-7}$ m/s;
- the Coffey design report references the geochemical testing carried out by Graeme Campbell & Associates in 2002. The geochemical assessment indicated that the tailings are potentially acid forming as a consequence of the high pyrite content. It was noted that neutral pH should prevail on the tailings beaches for deposition cycle times of up to 4 to 5 weeks during operation of the TSF. However, if left exposed for an extended period, the surface zone tailings are likely to develop a pH of 3 to 4. In practice, cycle times less than 4 to 5 weeks would be expected during normal operations;
- lime dosing of the decant pond was noted as a possible control measure to manage acid formation in the decant pond;
- it was recommended that further physical and geochemical characterisation (including kinetic testing) be carried out on the tailings; and
- the scope and findings of any tailings physical testing was not sighted.

4. Panorama Copper-Zinc Project, Geochemical Assessment of Tailing: Letter Report, Depyritised Tailing Samples GS3412 and GS3696, RGS Environmental, May 2009;

A review of this letter report indicated that:

- two samples of depyritised tailings materials were characterised using static geochemical tests and kinetic leach column tests;
- the objective of the kinetic leach tests was to investigate the real-time geochemical behaviour of the tailing materials over an initial period of six months in order to provide an indication of the ongoing quality of run-off/ seepage and therefore determine any implications for environmental management at the proposed TSF;
- surface run-off and leachate from the depyritised tailing materials is likely to be acidic and contain elevated concentrations of some soluble metals and salts;

- in comparison, surface run-off and leachate from the limestone amended depyritised tailing material is likely to be pH neutral and contain much lower concentrations of soluble metals; and
- following crushed limestone addition and exposure to oxidising conditions for six months, the only soluble metal with a concentration in leachate likely to be greater than the ANZECC/NEPM water quality guideline criteria is Selenium.

5. Pilbara Cu/Zn Project, Tailings Management, Conceptual Design Report, DE Cooper & Associates, February 2013; and
6. Pilbara Copper-Zinc Project: Geochemical Characterisation of Process-Tailings Slurry Samples (Sulphur Springs and Mons Cupri Deposits) – Implications for Process – Tailings Management, Graeme Campbell & Associates, November 2012.

A review of these reports indicated that:

- the tailings storage concept for the Panorama Project, under the ownership of CBH Sulphur Springs, proposed a conventional slurry tailings storage with decant system. The DE Cooper proposed concept comprised filtering of the tailings and compaction in a purpose built facility to form a dense mass;
- tailings physical testing comprised Rowe Cell, permeability, compaction and Atterberg Limits tests. These tests yielded the following parameters:
  - Maximum dry density – 2.33 t/$m^3$;
  - Optimum moisture content – 10.2%;
  - Permeability – 1.5 x $10^{-7}$ m/s;
  - Liquid limit – 20.5%;
  - Plastic limit – 15.5%;
  - Cohesion – 0 kPa; and
  - Angle of internal friction – 37 degrees.
- the tailings solids was characterised as follows:
  - a Sulphide-S value of 24.4%;
  - an Acid Neutralisation Capacity value of 5 kg $H_2SO_4$/tonne;
  - a Net Acid Generation value of 380-400 kg $H_2SO_4$/tonne and a NAG pH value of 1.6;
  - variously enriched in Zinc, Cadmium, Copper, Lead, Silver, Arsenic, Bismuth, Antimony, Selenium, Molybdenum, Mercury and Chromium;
  - pyrite and quartz were major components with sub-ordinate K-feldspar; and
  - classified as Potentially Acid Forming (PAF) through pyrite oxidation.
- the tailings slurry water sample was alkaline (pH 11.0-11.5) and of brackish salinity. At this pH value the concentration of minor elements were close to or below their respective detection limits;
- the kinetic testing indicated that the tailings-pore fluids within the surface zone tailings on a dormant beach within the active TSF should be circum-neutral (pH = 6 approximately) for about 2 weeks. However, during this period the pore fluid Zinc concentrations could increase to within 50-100 mg/L; and
- although difficult to project accurately, any seepage fluid within the sub-surface should have a pH value above approximately 3.

## 4.2 TAILINGS PHYSICAL TESTING

### 4.2.1 General

Tailings physical testing was carried out on two samples as part of the DFS, a Copper transition composite and a Zinc transition composite, to determine density and water release design parameters. The following information was provided by Lycopodium regarding the physical properties of the two tailings samples:

- Copper and zinc transition composites for bulk flotation;
- Target grind size is 63 µm;
- Copper Transition Composite target %solids w/w = 55%;
- Zinc Transition Composite target %solids w/w = 50%; and
- Transition ore representative of first 2.5 years of production.

The following tests were carried out on the samples:

- Classification tests to determine:
  - Particle size distribution of the tailings;
  - Supernatant liquor density and pH;
  - Tailings solids particle density; and
  - Atterberg limits of the tailings solids.
- Undrained and drained sedimentation tests;
- Air drying tests;
- Permeability tests; and
- High strain consolidation tests.

The results and recommendations associated with the physical testing programme are reported in detail in the DFS report. The main findings are presented in the following sections.

### 4.2.2 Water Production

The release of supernatant/underdrainage following deposition can be estimated based on the climatic conditions, particle size distribution and permeability of the tailings, and the results of the undrained and drained sedimentation tests. The rate of supernatant release will also affect the potential decant recovery.

The testing indicated that the rate of supernatant release for the Zn Tails was quick, with the majority of water released in under a day. The expected water release would be around 55 – 65% of the water in slurry, not accounting for rainfall and evaporation but considering the loss of water to re-saturate lower tailings layers.

Comparatively, the testing indicated that the rate of supernatant release for the Cu Tails was also relatively quick but slower than the Zn Tails, with the majority of water released in 1 - 2 days. The expected water release would be around 45 – 55% of the water in slurry, not accounting for rainfall and evaporation but considering the loss of water to re-saturate lower tailings layers.

### 4.2.3 Tailings Density

The settled dry density deposited into a tailings storage facility can be predicted from the laboratory test work, facility design and site climatic conditions. It has been observed over a number of years that densities achieved in the field are generally lower than those obtained in the laboratory. In addition, field densities achieved are dependent on the area available for drying and the thickness of deposited layers.

The tests provided final dry density values as follows:

Zn Tails
- Undrained test 1.64 t/m$^3$;
- Drained test 1.74 t/m$^3$; and
- Air drying test 2.15 t/m$^3$.

Cu Tails
- Undrained test 1.44 t/m$^3$;
- Drained test 1.70 t/m$^3$; and
- Air drying test 2.15 t/m$^3$.

The test work indicated that for the Zn Tails, there is a moderate difference in the density achieved between tailings based on settlement and tailings exposed to air drying. With suitable air drying of the tailings slurry a settled density of approximately 1.95 to 2.05 t/m$^3$ is expected in the facility.

For the Cu Tails there is a considerable difference in the density achieved between tailings based on settlement and tailings exposed to air drying. With suitable air drying of the tailings slurry, a settled density of approximately 1.9 to 2.0 t/m$^3$ is expected in the facility.

For both samples, the air drying test achieved a high density primarily associated with the high solids particle density. Assuming that the fresh ore is consistent with the high SG of the two transition ores it is recommended that the TSF filling model be modified to match the physical tailings testing results.

## 4.3 TAILINGS GEOCHEMICAL TESTING

### 4.3.1 General

Geochemical testing of the Copper and Zinc composite transition solids and supernatant was carried out, also as part of the DFS, to assess the acid generation potential, element enrichment and supernatant/seepage water quality against reference standards. The results and recommendations associated with the geochemical testing programme are reported in detail in the DFS report. The main findings are presented in the following sections.

### 4.3.2 Acid Forming Potential

The tailings samples are considered Potentially Acid Forming (PAF) based on extremely high NAPP values and acidic NAG pH values. The ANC values are very low and, as such, the lag time to acid generation is likely to be very short. Based on these results there is considered to be an extreme risk of acid generation within the tailings storage facility without adequate controls.

The most effective technique to eliminate acid generation is to operate the tailings facility sub-aqueously with a permanent water cover. However, this is unlikely to be sustainable based on the climate at the project site. Therefore, it is recommended that the tailings deposition be managed in such a way to prevent the tailings saturation levels from falling below 100%. Towards the end of the operating life pH amendment via lime addition should be conducted prior to tailings discharge to prevent the top surface of the tailings generating acid following cessation of sub-aerial deposition and prior to construction of the closure cover.

The closure cover presented in the DFS comprised a multi-layered cross-section designed to reduce infiltration into the tailings and lower the potential for acid generation from the tailings stored and incorporated a barrier layer (low permeability material/HDPE) overlain by a well-graded granular non-acid forming (NAF) layer to store and release retained moisture. The cross-section description adopted for the DFS included the following layers:

- A low permeability compacted sub-base layer (200 mm);
- A 1.0 mm or 1.5 mm HDPE liner;
- An HDPE protection layer (150 mm) consisting of silt, sand or rounded gravel materials;
- A NAF waste rock layer won from the waste dumps; and
- A topsoil cover equivalent in thickness to the topsoil removed from the basin area.

As part of an independent review of the DFS it was recommended that an additional layer of crushed limestone be incorporated into the closure cover. This layer would be constructed over the final tailings surface and would underlie the other closure cover layers with the purpose of providing additional neutralising capacity to any seepage permeating through the closure cover.

For the alternative TSF location, any seepage from the facility is expected to report to and be contained by the mine pit. Consequently the TSF cover design may not warrant inclusion of an HDPE liner.

#### 4.3.3 Multi-Element Enrichment

The samples recorded a high number of element enrichments, with the level of enrichment tending to vary from significant to high. Of particular note was Zinc which was recorded above the upper bound limit of detection of 50,000 mg/kg (5%) in one of the samples. As such, the TSF should be designed to contain all solids and appropriate operational controls will be required to limit dusting.

The multi-element concentrations also pose a risk to supernatant water quality unless the pH is adequately managed, as a reduction in pH would increase the solubility of several metals.

Comparison of the multi-element results to soil quality screening criteria indicates that the TSF will require a closure cover system that prevents plant uptake. However, in this case, the closure cover required to manage acid generation will also adequately manage the multi-element concentrations in the tailings solids.

#### 4.3.4 Supernatant Water Quality

The supernatant was found to be reasonable, although several metals were detected above reference water quality guidelines.

## 5. TAILINGS DEPOSITION MANAGEMENT

### 5.1 INTRODUCTION

The design of the TSF incorporates both a density model and a site water management model. The density model is dependent on the throughput, site climatic data and the deposition plan developed for the facility.

## 5.2 DEPOSITION PLAN

A deposition plan was developed for the facility. The plan is based on the following requirements:

- The total storage capacity required.
- The throughput and resulting tailings beach slope.
- The proposed deposition concept.

The TSF design is based on the throughputs and storage capacity summarised in Table 3.1 and the design criteria summarised in Table 3.2. A tailings beach slope of 0.83% (1V:120H) was adopted, based on the tailings laboratory testing and measured tailings beach slopes at other sites for similar tailings blends.

The deposition of tailings into the storage facility will be primarily from the north and south embankments. The tailings delivery pipeline will be routed from the process plant up to the crest of the TSF embankments. The tailings distribution pipeline will be located on the embankment crests and will be raised with each stage. Deposition will occur from multiple spigots inserted along the tailings distribution line (nominally 4 to 5 at a time). The deposition locations(s) will be moved progressively along the distribution line as required to control the location of the supernatant pond.

The tailings deposition modelling was undertaken using the RIFT TD tailings modelling package (Ref. 4). Rift TD is an advanced three-dimensional Digital Terrain Model specifically developed to model tailings deposition. The program develops a model of the tailings beach based on the original topography, provided deposition point locations, beach slopes and tailings tonnages. Figures 1 to 4 show the approximate extent of the tailings beach at the end of Years 2, 5, 8 and 10 of operation.

The estimated tailings levels at the northern and southern embankments at the end of each year of operation are summarised in Table 5.1.

**Table 5.1:** Estimated life of mine tailings levels

| Stage | Total Storage Capacity | Years of Capacity Per Lift | Tailings Level |
|---|---|---|---|
| | (Mt) | (Yrs) | (RL m) |
| 1 | 1.135 | 1.0 | 1336.1 |
| 2 | 2.27 | 1.0 | 1342.3 |
| 3 | 3.35 | 1.0 | 1346.0 |
| 4 | 4.375 | 1.0 | 1348.8 |
| 5 | 5.40 | 1.0 | 1351.1 |
| 6 | 6.425 | 1.0 | 1353.2 |
| 7 | 7.45 | 1.0 | 1355.1 |
| 8 | 8.475 | 1.0 | 1356.8 |
| 9 | 9.5 | 1.0 | 1358.3 |
| 10 | 10.53 | 1.0 | 1359.7 |

## 6. WATER BALANCE

Management of water relating to the tailings storage facility is critical in terms of the facility design and decant return pumping requirements. The DFS water management model was amended for the alternative TSF concept design in order to estimate the flows of water entering and exiting the facility and to determine design embankment crest levels for the TSF. The model was run with a repeating sequence of average conditions and the water balance under average conditions is summarised in Table 6.1. Based on the modelling the following conclusions can be made:

- Water available for decant return is 3.6 GL and varies between 15,000 $m^3$ and 72,000 $m^3$ per month. The maximum decant return rate (and therefore the required water treatment rate) is 110 $m^3$/hr;
- The supernatant pond volume remains at the minimum (20,000 $m^3$) except for 1 or 2 months during each wet season;
- The facility experiences a total water shortfall of 4 GL under average climatic conditions and ranges from approximately 5,000 to 83,000 $m^3$/month. The average shortfall is approximately 34,000 $m^3$/month;
- The TSF recycle to the process plant varies from 27% to 100% of water in slurry during the operation and ranges from 15,000 to 72,000 $m^3$/month. The average recycle over the operating life is 48% of the water in slurry; and
- Development of the tailings level at the main embankments and pond level under average conditions are presented in Table 6.1. Of note, the pond level is consistently below the tailings level (at the main embankments).

**Table 6.1:** Summary of TSF water balance – average climatic conditions

| Month | | Water In Slurry (m³/month) | Additional Water to TSF (m³/month) | Decant Return (m³/month) | Excess for Evaporation (m³/month) | Water Lost in TSF (m³/month) | Shortfall (m³/month) | Pond Volume (m³) | Pond RL (RLm) | Tails RL at Emb. (RLm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | Nov | 83004 | 0 | 23863 | 0 | 59141 | 83004 | 20000 | 1320.6 | 1320.6 |
| 14 | Dec | 85771 | 0 | 41150 | 0 | 44620 | 61908 | 20000 | 1321.4 | 1323.6 |
| 15 | Jan | 85771 | 0 | 39180 | 0 | 46590 | 44620 | 20000 | 1323.0 | 1325.7 |
| 16 | Feb | 77470 | 0 | 53861 | 0 | 23609 | 38290 | 20000 | 1324.2 | 1327.3 |
| 17 | Mar | 85771 | 0 | 43907 | 0 | 41864 | 31909 | 20000 | 1325.2 | 1328.8 |
| 18 | Apr | 83004 | 0 | 41341 | 0 | 41663 | 39097 | 20000 | 1326.2 | 1330.1 |
| 19 | May | 85771 | 0 | 40409 | 0 | 45362 | 44430 | 20000 | 1326.9 | 1331.3 |
| 20 | Jun | 83004 | 0 | 39398 | 0 | 43606 | 42595 | 20000 | 1327.7 | 1332.3 |
| 21 | Jul | 85771 | 0 | 40847 | 0 | 44924 | 46373 | 20000 | 1328.5 | 1333.4 |
| 22 | Aug | 85771 | 0 | 39161 | 0 | 46610 | 44924 | 20000 | 1329.4 | 1334.3 |
| 23 | Sep | 83004 | 0 | 35748 | 0 | 47256 | 43843 | 20000 | 1330.3 | 1335.2 |
| 24 | Oct | 85771 | 0 | 34536 | 0 | 51235 | 50023 | 20000 | 1331.2 | 1336.1 |
| 25 | Nov | 83004 | 0 | 32336 | 0 | 50668 | 48468 | 20000 | 1331.9 | 1336.8 |
| 26 | Dec | 85771 | 0 | 33890 | 0 | 51881 | 53435 | 20000 | 1333.0 | 1337.6 |
| 27 | Jan | 85771 | 0 | 40495 | 0 | 45276 | 51881 | 20000 | 1334.0 | 1338.2 |
| 28 | Feb | 77470 | 0 | 61177 | 0 | 16293 | 36975 | 20000 | 1334.6 | 1338.7 |
| 29 | Mar | 85771 | 0 | 46863 | 0 | 38908 | 24594 | 20000 | 1335.3 | 1339.2 |
| 30 | Apr | 83004 | 0 | 43514 | 0 | 39490 | 36141 | 20000 | 1335.7 | 1339.6 |
| 31 | May | 85771 | 0 | 40828 | 0 | 44943 | 42257 | 20000 | 1336.2 | 1340.1 |
| 32 | Jun | 83004 | 0 | 39407 | 0 | 43597 | 42176 | 20000 | 1336.7 | 1340.6 |
| 33 | Jul | 85771 | 0 | 41027 | 0 | 44743 | 46364 | 20000 | 1337.1 | 1341.0 |
| 34 | Aug | 85771 | 0 | 39184 | 0 | 46587 | 44743 | 20000 | 1337.6 | 1341.5 |
| 35 | Sep | 83004 | 0 | 35767 | 0 | 47237 | 43820 | 20000 | 1338.1 | 1342.0 |
| 36 | Oct | 85771 | 0 | 34546 | 0 | 51225 | 50004 | 20000 | 1338.4 | 1342.3 |
| 37 | Nov | 83004 | 0 | 32387 | 0 | 50617 | 48458 | 20000 | 1338.8 | 1342.7 |
| 38 | Dec | 85771 | 0 | 34095 | 0 | 51675 | 53384 | 20000 | 1339.1 | 1343.0 |
| 39 | Jan | 85771 | 0 | 42704 | 0 | 43066 | 51675 | 20000 | 1339.5 | 1343.4 |
| 40 | Feb | 77470 | 0 | 71427 | 0 | 6044 | 34766 | 20000 | 1339.8 | 1343.7 |
| 41 | Mar | 85771 | 0 | 50320 | 0 | 35451 | 14344 | 20000 | 1340.1 | 1344.0 |
| 42 | Apr | 83004 | 0 | 45655 | 0 | 37349 | 32684 | 20000 | 1340.4 | 1344.3 |
| 43 | May | 58037 | 0 | 23353 | 0 | 34683 | 12382 | 20000 | 1340.7 | 1344.6 |
| 44 | Jun | 56164 | 0 | 22112 | 0 | 34052 | 32811 | 20000 | 1341.0 | 1344.9 |
| 45 | Jul | 58037 | 0 | 23302 | 0 | 34735 | 35924 | 20000 | 1341.3 | 1345.2 |
| 46 | Aug | 58037 | 0 | 21391 | 0 | 36646 | 34735 | 20000 | 1341.5 | 1345.4 |
| 47 | Sep | 56164 | 0 | 18618 | 0 | 37546 | 34773 | 20000 | 1341.8 | 1345.7 |
| 48 | Oct | 58037 | 0 | 16924 | 0 | 41112 | 39418 | 20000 | 1342.1 | 1346.0 |
| 49 | Nov | 56164 | 0 | 15392 | 0 | 40772 | 39240 | 20000 | 1342.3 | 1346.2 |
| 50 | Dec | 58037 | 0 | 16637 | 0 | 41400 | 42644 | 20000 | 1342.6 | 1346.5 |
| 51 | Jan | 58037 | 0 | 26369 | 0 | 31667 | 41400 | 20000 | 1342.8 | 1346.7 |
| 52 | Feb | 52420 | 0 | 52420 | 0 | 0 | 26051 | 28916 | 1343.2 | 1346.9 |
| 53 | Mar | 58037 | 0 | 41191 | 0 | 16845 | 5616 | 20000 | 1343.3 | 1347.2 |
| 54 | Apr | 56164 | 0 | 29686 | 0 | 26478 | 14973 | 20000 | 1343.5 | 1347.4 |
| 55 | May | 58037 | 0 | 23561 | 0 | 34475 | 28350 | 20000 | 1343.7 | 1347.6 |
| 56 | Jun | 56164 | 0 | 22116 | 0 | 34048 | 32603 | 20000 | 1344.0 | 1347.9 |
| 57 | Jul | 58037 | 0 | 23385 | 0 | 34652 | 35920 | 20000 | 1344.2 | 1348.1 |
| 58 | Aug | 58037 | 0 | 21401 | 0 | 36635 | 34652 | 20000 | 1344.4 | 1348.3 |
| 59 | Sep | 56164 | 0 | 18626 | 0 | 37538 | 34763 | 20000 | 1344.6 | 1348.5 |
| 60 | Oct | 58037 | 0 | 16928 | 0 | 41109 | 39410 | 20000 | 1344.8 | 1348.7 |
| 61 | Nov | 56164 | 0 | 15413 | 0 | 40752 | 39236 | 20000 | 1345.1 | 1349.0 |
| 62 | Dec | 58037 | 0 | 16719 | 0 | 41318 | 42624 | 20000 | 1345.3 | 1349.2 |
| 63 | Jan | 58037 | 0 | 27264 | 0 | 30773 | 41318 | 20000 | 1345.5 | 1349.4 |
| 64 | Feb | 52420 | 0 | 52420 | 0 | 0 | 25156 | 33160 | 1345.9 | 1349.6 |
| 65 | Mar | 58037 | 0 | 45899 | 0 | 12138 | 5616 | 20000 | 1345.9 | 1349.8 |
| 66 | Apr | 56164 | 0 | 30633 | 0 | 25531 | 10266 | 20000 | 1346.1 | 1350.0 |
| 67 | May | 58037 | 0 | 23724 | 0 | 34313 | 27403 | 20000 | 1346.3 | 1350.2 |
| 68 | Jun | 56164 | 0 | 22120 | 0 | 34045 | 32441 | 20000 | 1346.5 | 1350.4 |
| 69 | Jul | 58037 | 0 | 23451 | 0 | 34585 | 35917 | 20000 | 1346.7 | 1350.6 |
| 70 | Aug | 58037 | 0 | 21409 | 0 | 36627 | 34585 | 20000 | 1346.9 | 1350.8 |
| 71 | Sep | 56164 | 0 | 18633 | 0 | 37532 | 34755 | 20000 | 1347.1 | 1351.0 |
| 72 | Oct | 58037 | 0 | 16931 | 0 | 41105 | 39404 | 20000 | 1347.2 | 1351.1 |
| 73 | Nov | 56164 | 0 | 15430 | 0 | 40734 | 39233 | 20000 | 1347.4 | 1351.3 |
| 74 | Dec | 58037 | 0 | 16791 | 0 | 41246 | 42606 | 20000 | 1347.6 | 1351.5 |
| 75 | Jan | 58037 | 0 | 28053 | 0 | 29984 | 41246 | 20000 | 1347.8 | 1351.7 |
| 76 | Feb | 52420 | 0 | 52420 | 0 | 0 | 24367 | 36915 | 1348.2 | 1351.9 |
| 77 | Mar | 58037 | 0 | 50101 | 0 | 7936 | 5616 | 20000 | 1348.2 | 1352.1 |
| 78 | Apr | 56164 | 0 | 31467 | 0 | 24698 | 6064 | 20000 | 1348.3 | 1352.2 |
| 79 | May | 58037 | 0 | 23868 | 0 | 34169 | 26570 | 20000 | 1348.5 | 1352.4 |
| 80 | Jun | 56164 | 0 | 22123 | 0 | 34042 | 32297 | 20000 | 1348.7 | 1352.6 |
| 81 | Jul | 58037 | 0 | 23510 | 0 | 34526 | 35914 | 20000 | 1348.8 | 1352.7 |
| 82 | Aug | 58037 | 0 | 21417 | 0 | 36620 | 34526 | 20000 | 1349.0 | 1352.9 |
| 83 | Sep | 56164 | 0 | 18638 | 0 | 37526 | 34748 | 20000 | 1349.2 | 1353.1 |
| 84 | Oct | 58037 | 0 | 16934 | 0 | 41102 | 39398 | 20000 | 1349.3 | 1353.2 |
| 85 | Nov | 56164 | 0 | 15446 | 0 | 40719 | 39230 | 20000 | 1349.5 | 1353.4 |
| 86 | Dec | 58037 | 0 | 16853 | 0 | 41183 | 42591 | 20000 | 1349.7 | 1353.6 |
| 87 | Jan | 58037 | 0 | 28731 | 0 | 29305 | 41183 | 20000 | 1349.8 | 1353.7 |

**Table 6.1 (cont'd):** Summary of TSF water balance – average climatic conditions

| Month | | Water In Slurry ($m^3$/month) | Additional Water to TSF ($m^3$/month) | Decant Return ($m^3$/month) | Excess for Evaporation ($m^3$/month) | Water Lost in TSF ($m^3$/month) | Shortfall ($m^3$/month) | Pond Volume ($m^3$) | Pond RL (RLm) | Tails RL at Emb. (RLm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 88 | Feb | 52420 | 0 | 52420 | 0 | 0 | 23689 | 40129 | 1350.3 | 1353.9 |
| 89 | Mar | 58037 | 0 | 53719 | 0 | 4318 | 5616 | 20000 | 1350.2 | 1354.1 |
| 90 | Apr | 56164 | 0 | 32187 | 0 | 23977 | 2445 | 20000 | 1350.3 | 1354.2 |
| 91 | May | 58037 | 0 | 23992 | 0 | 34044 | 25849 | 20000 | 1350.5 | 1354.4 |
| 92 | Jun | 56164 | 0 | 22125 | 0 | 34039 | 32172 | 20000 | 1350.6 | 1354.5 |
| 93 | Jul | 58037 | 0 | 23562 | 0 | 34474 | 35911 | 20000 | 1350.8 | 1354.7 |
| 94 | Aug | 58037 | 0 | 21423 | 0 | 36614 | 34474 | 20000 | 1350.9 | 1354.8 |
| 95 | Sep | 56164 | 0 | 18644 | 0 | 37521 | 34741 | 20000 | 1351.1 | 1355.0 |
| 96 | Oct | 58037 | 0 | 16937 | 0 | 41100 | 39393 | 20000 | 1351.2 | 1355.1 |
| 97 | Nov | 56164 | 0 | 15460 | 0 | 40705 | 39228 | 20000 | 1351.4 | 1355.3 |
| 98 | Dec | 58037 | 0 | 16909 | 0 | 41127 | 42577 | 20000 | 1351.5 | 1355.4 |
| 99 | Jan | 58037 | 0 | 29348 | 0 | 28689 | 41127 | 20000 | 1351.7 | 1355.6 |
| 100 | Feb | 52420 | 0 | 52420 | 0 | 0 | 23073 | 43064 | 1352.1 | 1355.7 |
| 101 | Mar | 58037 | 0 | 57045 | 0 | 992 | 5616 | 20880 | 1352.0 | 1355.8 |
| 102 | Apr | 56164 | 0 | 33522 | 0 | 22642 | 0 | 20000 | 1352.1 | 1356.0 |
| 103 | May | 58037 | 0 | 24108 | 0 | 33928 | 24514 | 20000 | 1352.2 | 1356.1 |
| 104 | Jun | 56164 | 0 | 22128 | 0 | 34037 | 32056 | 20000 | 1352.4 | 1356.3 |
| 105 | Jul | 58037 | 0 | 23611 | 0 | 34425 | 35909 | 20000 | 1352.5 | 1356.4 |
| 106 | Aug | 58037 | 0 | 21429 | 0 | 36607 | 34425 | 20000 | 1352.6 | 1356.5 |
| 107 | Sep | 56164 | 0 | 18648 | 0 | 37516 | 34735 | 20000 | 1352.8 | 1356.7 |
| 108 | Oct | 58037 | 0 | 16939 | 0 | 41097 | 39388 | 20000 | 1352.9 | 1356.8 |
| 109 | Nov | 56164 | 0 | 15473 | 0 | 40691 | 39225 | 20000 | 1353.0 | 1356.9 |
| 110 | Dec | 58037 | 0 | 16965 | 0 | 41072 | 42563 | 20000 | 1353.2 | 1357.1 |
| 111 | Jan | 58037 | 0 | 29960 | 0 | 28077 | 41072 | 20000 | 1353.3 | 1357.2 |
| 112 | Feb | 52420 | 0 | 52420 | 0 | 0 | 22461 | 46000 | 1353.8 | 1357.3 |
| 113 | Mar | 58037 | 0 | 58037 | 0 | 0 | 5616 | 24230 | 1353.6 | 1357.4 |
| 114 | Apr | 56164 | 0 | 36774 | 0 | 19391 | 0 | 20000 | 1353.7 | 1357.6 |
| 115 | May | 58037 | 0 | 24225 | 0 | 33811 | 21263 | 20000 | 1353.8 | 1357.7 |
| 116 | Jun | 56164 | 0 | 22130 | 0 | 34034 | 31939 | 20000 | 1353.9 | 1357.8 |
| 117 | Jul | 58037 | 0 | 23660 | 0 | 34376 | 35906 | 20000 | 1354.1 | 1358.0 |
| 118 | Aug | 58037 | 0 | 21435 | 0 | 36601 | 34376 | 20000 | 1354.2 | 1358.1 |
| 119 | Sep | 56164 | 0 | 18653 | 0 | 37511 | 34729 | 20000 | 1354.3 | 1358.2 |
| 120 | Oct | 58037 | 0 | 16942 | 0 | 41095 | 39383 | 20000 | 1354.4 | 1358.3 |
| 121 | Nov | 56164 | 0 | 15487 | 0 | 40677 | 39223 | 20000 | 1354.5 | 1358.4 |
| 122 | Dec | 58037 | 0 | 17021 | 0 | 41015 | 42550 | 20000 | 1354.6 | 1358.5 |
| 123 | Jan | 58037 | 0 | 30586 | 0 | 27451 | 41015 | 20000 | 1354.8 | 1358.7 |
| 124 | Feb | 52420 | 0 | 52420 | 0 | 0 | 21835 | 49014 | 1355.2 | 1358.8 |
| 125 | Mar | 58037 | 0 | 58037 | 0 | 0 | 5616 | 27686 | 1355.1 | 1358.9 |
| 126 | Apr | 56164 | 0 | 40168 | 0 | 15996 | 0 | 20000 | 1355.1 | 1359.0 |
| 127 | May | 58037 | 0 | 24348 | 0 | 33689 | 17869 | 20000 | 1355.2 | 1359.1 |
| 128 | Jun | 56164 | 0 | 22133 | 0 | 34032 | 31817 | 20000 | 1355.3 | 1359.2 |
| 129 | Jul | 58037 | 0 | 23712 | 0 | 34324 | 35904 | 20000 | 1355.4 | 1359.3 |
| 130 | Aug | 58037 | 0 | 21442 | 0 | 36595 | 34324 | 20000 | 1355.6 | 1359.5 |
| 131 | Sep | 56164 | 0 | 18659 | 0 | 37506 | 34723 | 20000 | 1355.7 | 1359.6 |
| 132 | Oct | 58037 | 0 | 16944 | 0 | 41092 | 39378 | 36944 | 1356.0 | 1359.7 |
| | **Total** | **7,648,363** | **-** | **3,643,041** | **-** | **4,005,322** | **4,026,891** | | | |

# 7. TSF PRELIMINARY CONCEPT DESIGN

## 7.1 EMBANKMENT STAGING AND CONSTRUCTION

The TSF consists of a cross-valley storage that will be operated as a single cell facility. The facility will comprise a main embankment located upstream of the open pit with the final stage downstream toe outside the perimeter of the pit abandonment bund, and a primary saddle dam located along the ridgeline at the southern end of the catchment. Secondary saddle dams will be required later in the facility life (from Year 9) to contain the tailings beach and provide for the design storm storage capacity. Figure 5 presents a general arrangement plan of the facility.

The estimated main embankment and saddle dam levels at each stage are shown in Table 7.1. Preliminary calculations indicate that there will be of the order of 500,000 $m^3$ of storm capacity throughout the facility life, which is in excess of the 1 in 1,000 year 72 hour design storm capacity required for a High B consequence category facility.

**Table 7.1:** Preliminary embankment levels

| Stage | Total Storage Capacity (Mt) | Years of Capacity Per Lift (Yrs) | Tailings RL (RL m) | Main/ Southern Saddle Embankment Level (RL m) | North-west Saddle Embankment Level (RL m) | West Saddle Embankment Level (RL m) |
|---|---|---|---|---|---|---|
| 1 | 1.135 | 1.0 | 1336.1 | 1,337.0 | | |
| 2 | 2.27 | 1.0 | 1342.3 | 1,343.0 | | |
| 3 | 3.35 | 1.0 | 1346.0 | 1,346.5 | | |
| 4 | 4.375 | 1.0 | 1348.8 | 1,349.5 | | |
| 5 | 5.40 | 1.0 | 1351.1 | 1,352.0 | | |
| 6 | 6.425 | 1.0 | 1353.2 | 1,354.0 | | |
| 7 | 7.45 | 1.0 | 1355.1 | 1,356.0 | | |
| 8 | 8.475 | 1.0 | 1356.8 | 1,357.5 | | |
| 9 | 9.5 | 1.0 | 1358.3 | 1,359.0 | 1,358.0 | 1,356.0 |
| 10 | 10.53 | 1.0 | 1359.7 | 1,360.5 | 1,359.5 | 1,358.0 |

The embankments will be constructed as multi-zoned earth and rockfill dams, using downstream methods, and will consist of a 6 m wide low permeability zone (Zone A) won from local borrow or selected suitable mine waste. The downstream structural zone (Zone C) will be constructed of run of mine waste from the open pit or local borrow. A transition zone (Zone B) is designed to ensure filter compatibility been the Zone A and Zone C materials.

The initial embankments will have upstream and downstream slopes of 1V:3H with a crest width of 10 m. The same crest width will be adopted for subsequent stages. The design is based on all lifts being constructed using mine waste and local borrow. The embankment downstream face will comprise 1V:3H inter-bench slopes located at 10 m vertical intervals and with 5 m wide berms, producing an overall downstream slope of 1V:3.5H. Typical embankment sections and details are shown in figures 6 and 7.

Construction of the downstream stage raises would be scheduled so that there is adequate storage volume (storm and tailings) available throughout the operating life of the facility.

## 7.2 SEEPAGE CONTROL

Based on the premise that seepage from this catchment will report to the open pit, the alternative TSF could be either unlined or partially lined depending on the calculated seepage rates under operating and closure scenarios. The facility would incorporate an underdrainage system and an upstream toe drain designed to drain by gravity to a collection sump located at the toe of the main embankment.

A preliminary assessment of existing ground slope within the valley indicates that ground slopes of less than 1V:3H (typically the target maximum slope for HDPE lining) and between 1V:2H and 1V:3H (absolute maximum for HDPE lining) are predominant along the base and upper slopes of the valley (Figure 8). In acknowledgement of the valley terrain and recognising that the majority of seepage will tend to occur along the valley base particularly below the supernatant pond, a partial basin liner combined with an underdrainage system may provide adequate control of seepage from the facility. This will need to be assessed in greater detail by means of seepage modelling and hydrogeological modelling to confirm the flow rates and flow paths of seepage exiting the facility.

A geotechnical investigation and detailed engineering geological assessment of the proposed TSF site will be carried out to inform the detailed design of the facility and address the potential for hydraulic connection between the TSF and the open pit/ underground workings.

## 7.3 DECANT RECOVERY

Tailings would be discharged into the facility by sub-aerial deposition methods, via spigots spaced at regular intervals along the northern and southern embankment crests, driving the pond towards the centre of the valley. A series of decants would be used to recover water with the water pumped to a water treatment plant for acid neutralisation and heavy metal removal prior to its return to the process plant.

## 7.4 SPILLWAY

In the event that the storage capacity of the facility was exceeded, water which could not be stored within the facility would discharge via an engineered spillway. The emergency spillway during operation would be designed to convey run-off from the Probable Maximum Flood (PMF), assuming that the decant pond level is at the spillway invert level at commencement of the storm event. A new spillway would be constructed at each stage of construction.

# 8. TSF OPERATION

## 8.1 TAILINGS DEPOSITION SYSTEM

The deposition of tailings into the storage facility will be from the north and south TSF embankments. The tailings delivery pipeline will be routed from the process plant up to the crest of each of these embankments. The tailings distribution pipeline will be located on the embankment crest and will be raised with each stage.

Deposition will occur from single offtakes inserted along the tailings distribution pipelines. The deposition location will be moved on a daily basis to one of the deposition points, or as required to control the location of the supernatant pond.

## 8.2 DEPOSITION TECHNIQUE

Tailings deposition will be carried out using the sub-aerial technique in order to promote the maximum amount of water removal from the facility by the formation of a large beach for drying and draining. Together with keeping the pond size to a minimum, sub-aerial deposition will increase the settled density of the tailings and hence maximise the storage potential and efficiency of the facility.

The tailings will be deposited into the facility in such a way as to encourage the formation of beaches over which the slurry will flow along the spine of the basin in a laminar non-turbulent manner. Limited settlement and water release will occur. The released water will form a thin film on the surface of the tailings. This water will flow to the supernatant pond from where it will be removed from the storage area via a decant tower. The Stage 1 decant tower will be located such that it will first receive water approximately 1 to 2 months after commissioning the facility.

Deposition of the tailings will be carried out on a cyclic basis with the tailings being deposited over one area of the storage until the required layer thickness has been built up. Deposition will then be moved to an adjacent part of the storage to allow the deposition layer to dry and consolidate. This will facilitate maximum storage to be achieved across the whole valley.

After deposition on a particular area of beach ceases and settling of the tailings has been completed, further de-watering will take place due partly to drainage into the underdrainage system, but mainly due to evaporation. As water evaporates and the moisture content drops, the volume of tailings will reduce to maintain a condition of full saturation within the tailings. This process will continue until interaction between the tailings particles negates volume reduction.

## 8.3 TSF MONITORING

### 8.3.1 Monitoring Programme

As part of the operation of the facility, extensive monitoring of all aspects of the operation should be undertaken. This monitoring falls into three basic categories:

- Short-term operation monitoring – this includes items such as offtake location, whether pipe joints are leaking, etc., which are part of ensuring that the facility is operating smoothly;
- Compliance monitoring – this includes items such as checking survey pins on embankment crests to monitor embankment movement, monitoring bores downstream of the TSF to monitor groundwater level and chemistry, and standpipe piezometers within each embankment to monitor the phreatic

surface, which are used to ensure that the project is meeting all of its commitments in regard to a safe, secure operation; and
- Long-term performance monitoring – this includes such items as tailings level surveys and water flow measurements, etc., which are used to monitor the long term performance of the facility and refine future embankment lift levels and final tailings extent.

If the monitoring programme indicated that potential problems were developing, an increase in monitoring frequency would be implemented and a response plan developed.

A detailed monitoring programme will be provided as part of the operating manual for the facility.

#### 8.3.2 Seepage Monitoring

Six groundwater monitoring stations (bores MB1 to MB6) are proposed to be installed around the facility to facilitate early detection and remediation of any seepage which may occur due to operation of the facility. Each monitoring station will consist of one shallow hole, extending through approximately 5 - 10 m of the near surface horizon, and one deep hole terminating approximately 5 m below the groundwater table. The shallow bore is intended to detect any seepage from the TSF flowing within the surface sediment, whilst the deep bore will monitor any changes in the chemical composition of the groundwater. Each borehole will be cased and screened over an interval set in the field during installation and sealed back to surface with low permeability grout. It is recommended that the monitoring boreholes are constructed before commissioning the TSF to accumulate baseline data specific to the storage location.

#### 8.3.3 Stability Monitoring

Pore water pressures should be monitored within the TSF embankments to ensure that stability is not compromised. To this end it is proposed that standpipe piezometers are installed at three locations on each of the main embankment crests. The base of the piezometers will be located within the embankment to ensure that the phreatic surface within the embankment fill is measured, as opposed to natural groundwater level. During each embankment raise the existing piezometers will be sealed with cement/bentonite grout mix. New piezometers will be established on the embankment crest at the end of raise construction.

Survey pins will be installed along the main embankment crests and downstream face to monitor any movement of the embankments. Any displacement which is considered excessive or ongoing may indicate embankment stability problems and would be assessed by a qualified geotechnical engineer.

#### 8.3.4 Tailings Performance Monitoring

Tailings performance monitoring will include monitoring of the following parameters on a continuous basis:

- Solids tonnage to the tailings storage facility;
- Water volume to the tailings storage facility;
- Rainfall and evaporation at the facility;
- Water return from the facility; and
- Collection efficiency of the underdrainage system based on underdrainage sump pump monitoring.

Monitoring of tailings moisture contents and densities, and survey of the tailings beach and supernatant pond locations should be conducted four times a year.

8.3.5 Emergency Controls

Under normal operating conditions the following systems should be in place:

- The tailings pipelines will be located on the upstream crest of the embankments, which will have a minimum crossfall to the tailings beaches of 2%. Any leakage from the pipeline will therefore flow towards the tailings storage facility; and
- Between the plant site and the TSF, the tailings delivery pipeline and water return lines will be contained within a bunded easement or buried, and equipped with an automatic pressure drop cut-out. This will reduce the risk of uncontrolled release of tailings or supernatant in the event of a pipe burst.

These systems should greatly reduce the likelihood of uncontrolled spillages from the TSF.

## 9. TSF CLOSURE

### 9.1 CLOSURE CONCEPT

The closure concept for the facility is based on the following principles:

- The surface will be water shedding with no potential ponding;
- The surface will need to be erosion resistant; and
- The surface infiltration rate will need to be lower than the seepage rate out of the base of the facility.

### 9.2 COMPLETION CRITERIA

The following completion criteria apply to the closure design of the TSF:

- Final landform – the extent of erosion of the rehabilitated TSF embankments will be similar to that of the naturally occurring colluvial slopes in the project area;
- Vegetation and biodiversity – post-closure vegetation will be similar to the pre-mining vegetation in terms of cover, density, species diversity and weed occurrence;
- Water quality and quantity – there will be no significant impairment of the pre-mining beneficial uses of groundwater; and
- Soil quality – the chemical and physical condition of post-closure surface soils will not impede plant growth.

### 9.3 LANDFORM MODELLING

Long-term (1000 years) Landform Evolution Modelling was carried out for the DFS to assess the behaviour and performance of the TSF post-closure using the SIBERIA software developed by Telluric Research for landform modelling (Ref. 5). The modelling was carried out to:

- Confirm that the resultant landform is geomorphically stable;
- Identify those issues associated with the cover design that affect the landform performance;
- Identify any potential TSF design changes which may mitigate long-term erosion issues;
- Establish, within an order of magnitude, the likely changes in the TSF landform over a 1,000 year period; and

- Identify the subsequent information required to refine the model in the feasibility study.

The base case for the modelling was the TSF after closure with the barrier store and release cover system as described by O'Kane (Ref. 6). The cover system adopted by O'Kane has a multi-layered cross-section designed to reduce infiltration into the tailings and lower the potential for acid generation from the tailings stored. Achievement of this objective requires the development of a barrier layer (low permeability material/HDPE) over which a well-graded granular non-acid forming (NAF) layer is placed to store and release retained moisture. The cross-section description included the following range of dimensions:

- Low permeability soil liner – 200 mm;
- 1.0 or 1.5 mm HDPE liner;
- Protective sand layer –150 mm minimum;
- Well graded NAF layer – 1,560 mm to 2,650 mm; and
- Topsoil – nominal thickness.

This design was built into the digital terrain model which was then incorporated into the software for processing. Climate data used was drawn from the historic data collected in the period 1889 - 2017 and processed through the SILO data drill. A 1,000 year dataset was applied by taking the 100 year analysis and applying it 10 times in the SIBERIA model. The 1,000 year landscape evolution modelling was undertaken based on the DFS design of the TSF. There are three areas in which erosion effects occur as follows:

- On the surface of the cover area leading towards the spillway location;
- Around the perimeter of the cover where it interacts with the surrounding valley walls; and
- On the embankment face, in particular along the berm on the embankment face.

The following design modifications were incorporated into the DFS design to reduce or mitigate these effects as follows:

- Cover surface – the depth of erosion on the surface area is about 0.15 m up to a peak value of around 0.3 to 0.4 m. The cover design from O'Kane has an overall depth of 2 to 3 m and thus the expected level of erosion will not expose the HDPE liner within the cover. Notwithstanding this, some additional modifications to the cover design were recommended as follows:
  - Mix the topsoil layer into the surface zone of the growth medium layer;
  - Ensure that the surface zone (mixed topsoil/growth medium) has a base quantity (% of material) of gravel to cobble sized material present to improve erosion resistance; and
  - Restore the vegetation cover as soon as possible on completion of placement of the cover layers consistent with the existing moderately dense surface cover.
- Edge of the cover against the valley sides – the model has an assumed flat surface which meets the sloping valley hillside. This relatively sharp interface focuses water flow and thus results in a localised erosion issue. During construction of the cover the edges of the cover around the perimeter should be shaped to extend up and integrate into the hillside face. In addition, coarser material will be added in these areas to improve erosion resistance. The design concept is to draw the water away from the edge of the cover out onto the surface and also to reduce local erosion by increasing the erosion resistance in this area;

- Embankment face and berm – the berm on the downstream face of the embankment has been provided in accordance with the current embankment facility guidelines; however the berm does act as a focus point for erosion in the post closure condition. The following changes to the embankment were incorporated into the design:
  - The downstream face of the last stage of the embankment will consist of large size erosion resistant material to reduce the erosion potential. The topsoil will be mixed with this coarse material;
  - The profile of the berm should be sloped to the outside edge so it will act as a velocity inhibitor for rainfall run-off but not store any water on the berm itself;
  - The possibility of completely removing the berm as part of the post closure works should be assessed in more detail; and
  - Vegetation establishment on the face of the embankment consistent with vegetation established on existing steeper hill faces in the area should be incorporated into the embankment on completion of the final embankment lift.

It is expected that the issues associated with closure and changes in the landform associated with design of the alternative TSF will be very similar to those identified by the landform modelling of the DFS design. The conceptual closure design has considered and accounted for these factors. Detailed design of the TSF will need to verify the assumptions and findings of the landform modelling as they relate to the proposed alternative site.

### 9.4 TAILINGS STORAGE FACILITY CLOSURE

Based on the above principles the tailings storage facility will be closed in the following sequence:

- Drain the decant pond using the water treatment plant;
- Continue to drain the tailings mass by operating the underdrainage system;
- Shape the tailings profile to be water shedding. This will be relatively straightforward as the deposition profile will provide a tailings surface sloping towards the centre of the facility. The facility closure spillway will be cut through the west saddle;
- Cover the tailings surface with a multiple layer low infiltration, erosion resistant water shedding cover; and
- Shut down the underdrainage system and close out the facility.

Figure 9 shows typical details of the proposed closure capping.

## 10. DETAILED DESIGN

Detailed design of the alternative TSF will be carried out in accordance with the requirements of the Department of Mines, Industry Regulation and Safety (DMIRS formerly DMP) “Code of Practice, Tailings storage facilities in Western Australia” (Ref. 2) and the Australian National Committee on Large Dams (ANCOLD) “Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure” (Ref. 3) and will augment the scope of work undertaken as part of the DFS design. The scope of work is expected to include:

i) Dam breach assessment and confirmation of the facility consequence category.
ii) Confirmation of the design criteria for the defined consequence category (storm storage, freeboard capacity, spillway capacity, design earthquake loading, stability factors of safety, dam safety/inspection requirements).
iii) Geotechnical investigation and detailed engineering geological assessment of the proposed TSF site to confirm the in situ ground conditions, to inform the detailed design of the facility and the potential for hydraulic connection between the TSF and the open pit/ underground workings, to confirm the geotechnical design parameters, and to establish potential sources of borrow material for construction.
iv) Siting of the TSF based on in situ ground conditions, topographical constraints and pit closure abandonment bund alignment.
v) Seepage analyses to evaluate seepage through the embankment and foundation of the TSF under normal operating conditions, a range of post closure conditions, and to approximate the phreatic surface and porewater pressures in the tailings and embankment.
vi) Stability modelling to assess the stability of the TSF embankments under static and post-seismic cases in order to confirm adequate factors of safety against the ANCOLD design criteria. A site specific seismic hazard assessment was carried out for the Sulphur Springs project site as part of the DFS. The assessment included probabilistic and deterministic seismic hazard analyses and provided recommended seismic design parameters.
vii) Water balance modelling for the TSF in order to understand and control the flow of water entering and exiting the facility and to determine design embankment crest levels for the TSF to cater for extreme storm events.
viii) Confirmation of TSF embankment levels and geometry incorporating storm storage, stability and spillway design analyses.
ix) Closure requirements to provide a landform that is geomorphically stable in the long term.

## 11. CONCLUSIONS

The key conclusions to arise from the preliminary assessment of the alternative TSF design concept are as follows:

- Storage of the projects' 10.53 Mt of tailings in the PSC5 catchment in accordance with requirements of the Department of Mines, Industry Regulation and Safety (DMIRS formerly DMP) "Code of Practice, Tailings storage facilities in Western Australia" and the Australian National Committee on Large Dams (ANCOLD) "Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure is feasible;
- The facility is assessed to be a High B consequence category, primarily a function of the Population at Risk due to the facility location above the open pit. This category defines the design and operational criteria for the facility;
- Locating a facility in this valley offsets the requirement to construct and maintain a pit diversion dam during operations and post-closure;
- The storage is relatively inefficient in terms of storage capacity:embankment fill ratio;

- Constructing a TSF in this location will present specific challenges due to the terrain. Constructability will need to be assessed in greater detail, particularly with respect to any consideration of the installation of an HDPE liner;
- The type and extent of facility lining will need to be confirmed by means of detailed seepage analyses and hydrogeological modelling to confirm the quantity and flow path/s of seepage from the facility; and
- A detailed geotechnical investigation and assessment of the engineering geology of the proposed TSF site will be required to inform the detailed design of the facility and address the potential for hydraulic connection between the TSF and the open pit/underground workings. The investigation will be undertaken during the next phase of design work.

We trust that this memorandum meets with your requirements. Should you have any questions please do not hesitate to contact us.

Yours faithfully
**KNIGHT PIÉSOLD PTY LTD**

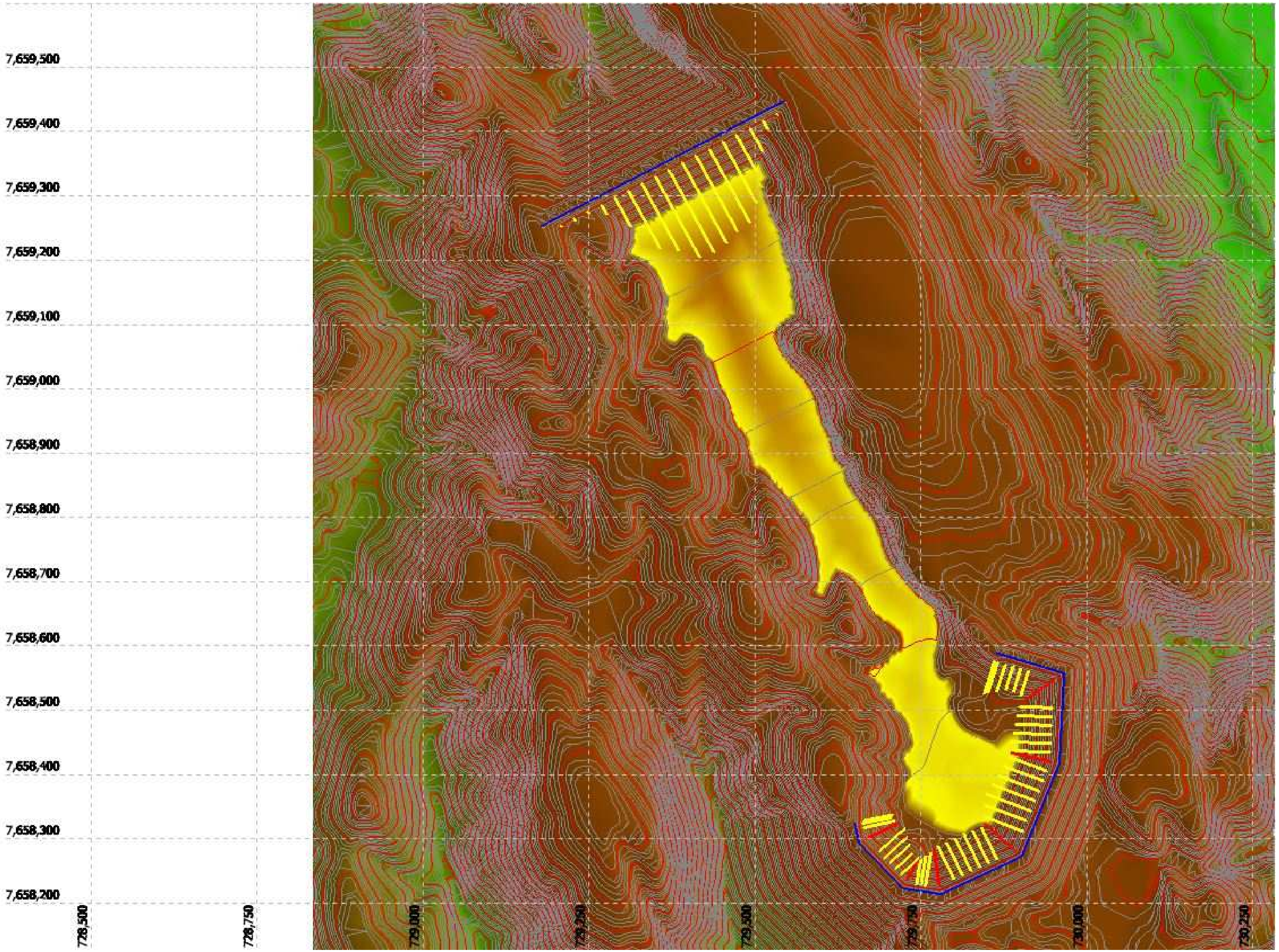
**SIMON SMITH**
Senior Engineer

**DAVID MORGAN**
Managing Director

**REFERENCES**

1. Tailings Management, Definitive Feasibility Study Rev. 0, Knight Piésold Pty Ltd, October 2018.
2. Department of Mines and Petroleum, Code of Practice, Tailings storage facilities in Western Australia, 2013.
3. Australian National Committee on Large Dams (ANCOLD), Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure, Revision 1, July 2019.
4. RIFT TD, Rift Software (https://www.riftxone.com/), 2018.
5. "User Manual for Siberia (Version 8.30)" Prof. Garry Willgoose, Telluric Research, July 2005.
6. "Sulphur Springs Conceptual TSF Cover Design" Memorandum, O'Kane Consultants Pty Ltd, 8 May 2017.

FIGURES

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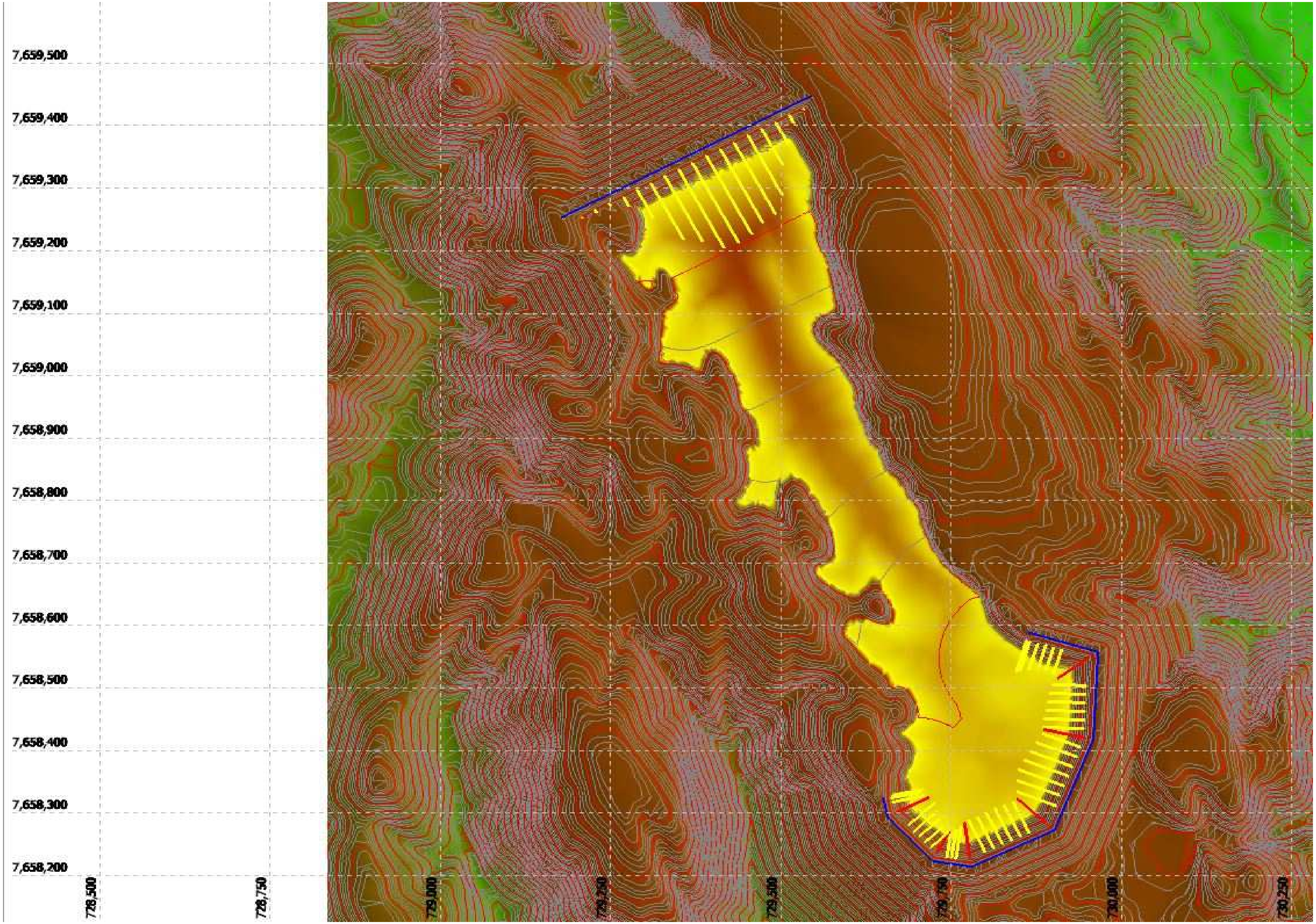
SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION - YEAR 2

PE801-00300 M20002
Figure 1

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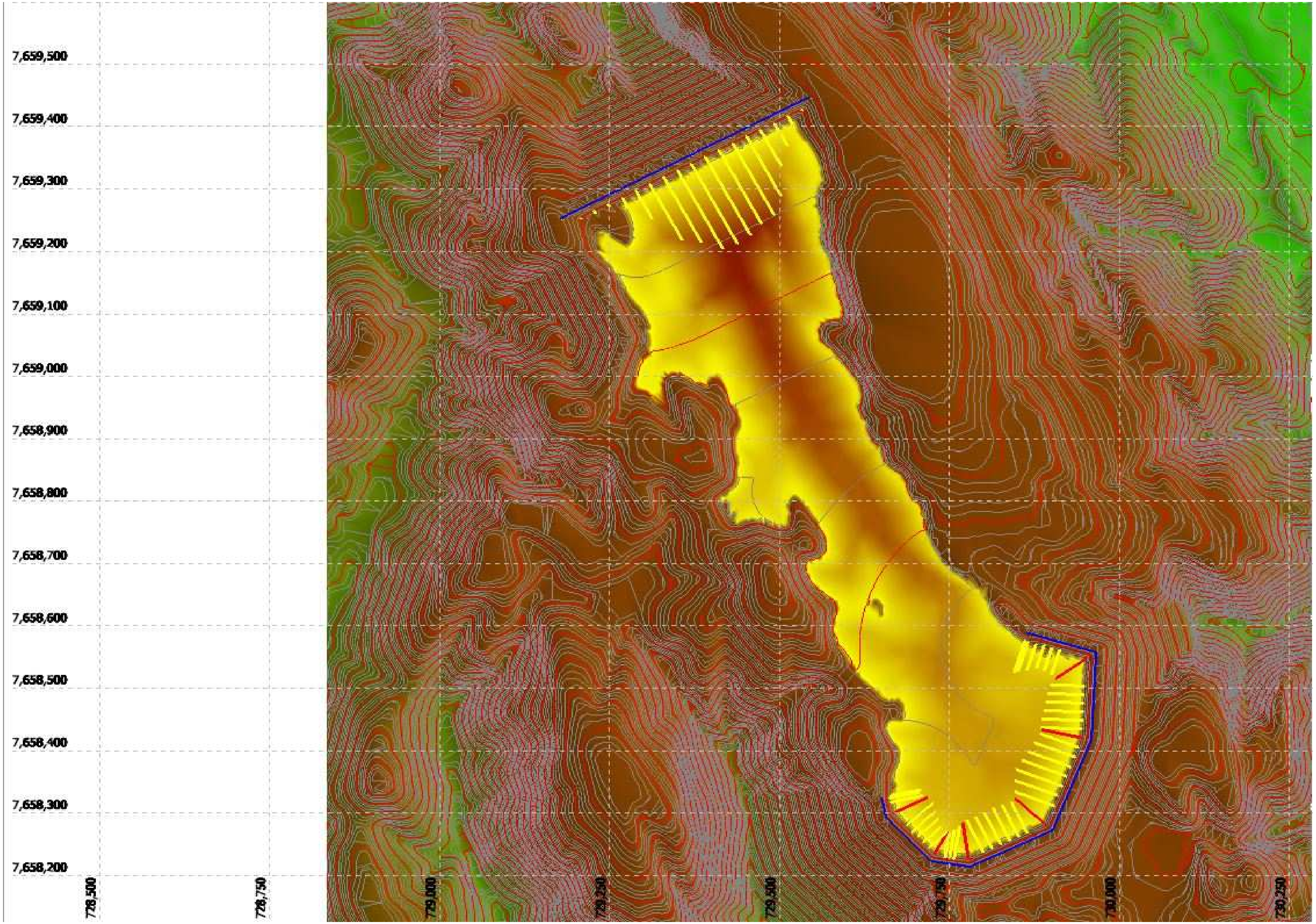
SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION - YEAR 5

PE801-00300 M20002
Figure 2

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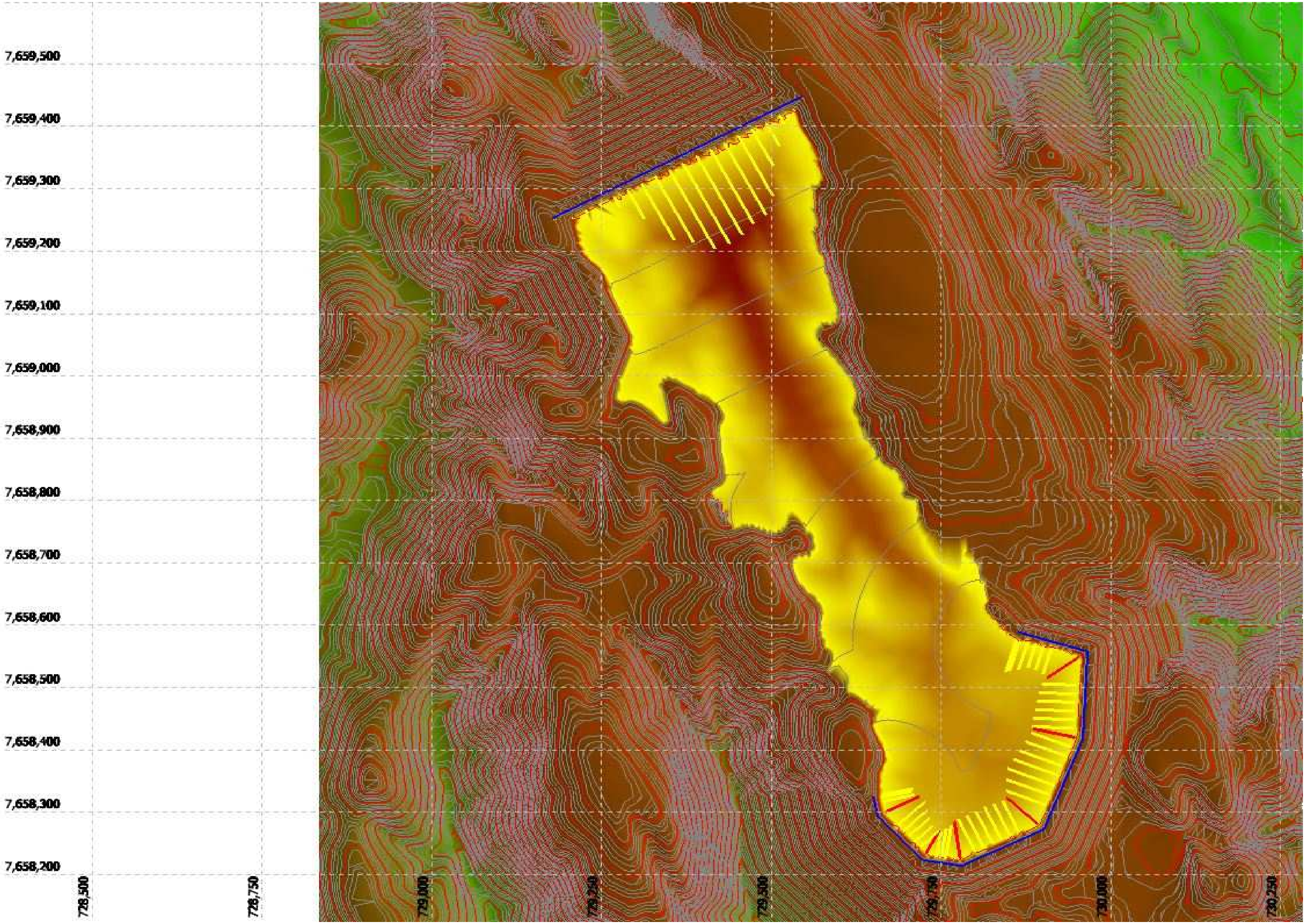
SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION - YEAR 8

PE801-00300 M20002
Figure 3

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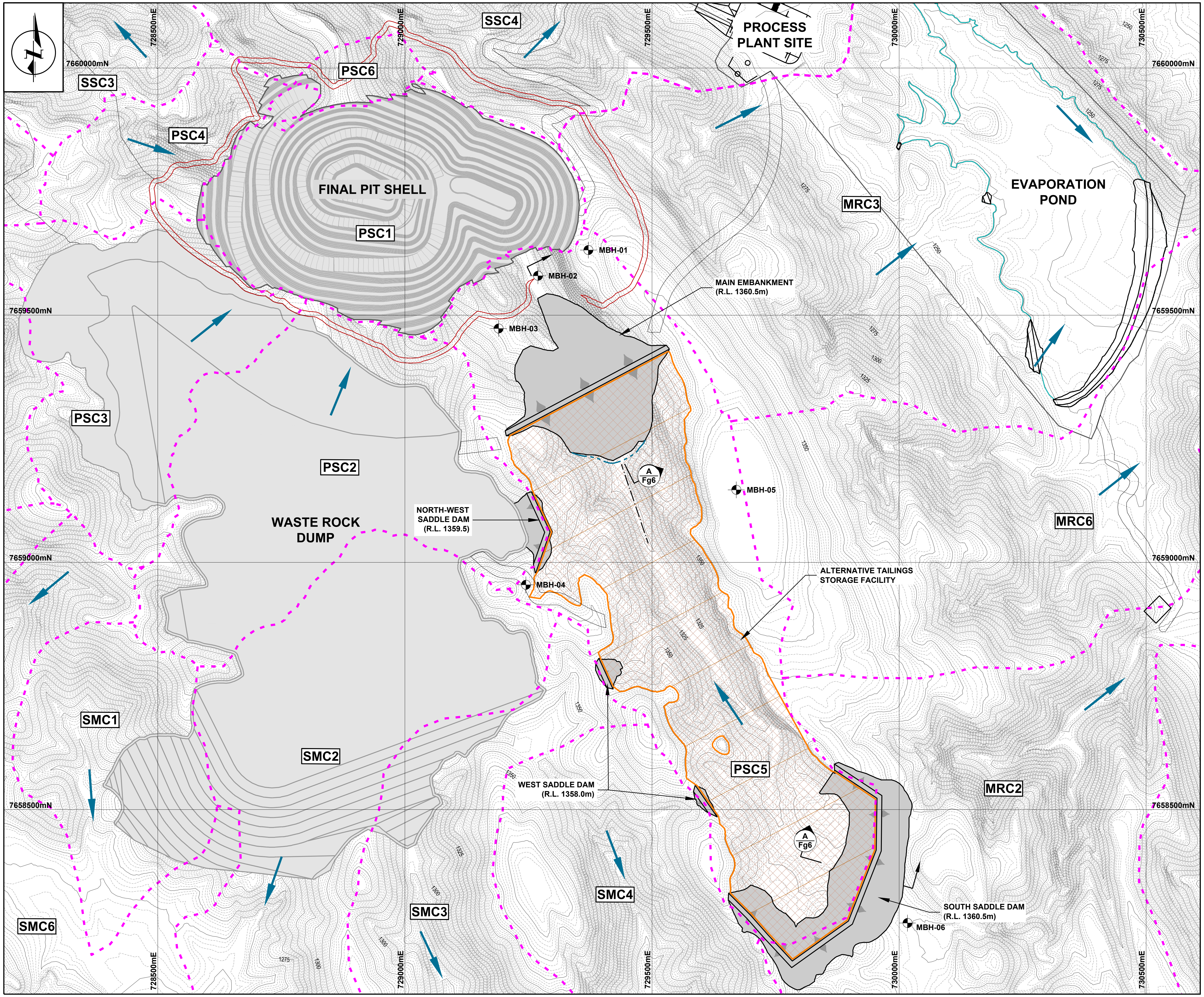
SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION - YEAR 10

PE801-00300 M20002
Figure 4




## NOTES:

1. 1m CONTOUR INTERVAL SHOWN. 2m CONTOUR INTERVAL TOPOGRAPHIC DATA PROVIDED BY VENTUREX RESOURCES LIMITED, AUGUST 2018.
2. PLANT SITE LAYOUT PROVIDED BY VENTUREX RESOURCES LIMITED, JANUARY 2020.
3. WASTE DUMP LAYOUT PROVIDED BY VENTUREX RESOURCES LIMITED, JANUARY 2020.
4. PIT SHELL AND PIT ABANDONMENT BUND PROVIDED BY VENTUREX RESOURCES LIMITED, JANUARY 2020.

## LEGEND:

- PIT ABANDONMENT BUND
- NATURAL GROUND CATCHMENT BOUNDARY
- #### DRAINAGE CATCHMENT I.D.
- NATURAL CATCHMENT RUN-OFF DIRECTION
- TAILINGS BEACH EXTENT
- EMBANKMENT TOE DRAIN
- MAIN COLLECTOR DRAIN
- PROPOSED MONITORING BOREHOLE LOCATIONS

## PROPOSED MONITORING BOREHOLE LOCATIONS

| MBH I.D. | EASTING | NORTHING |
|---|---|---|
| MBH-01 | 729371 | 7659632 |
| MBH-02 | 729269 | 7659580 |
| MBH-03 | 729189 | 7659473 |
| MBH-04 | 729245 | 7658954 |
| MBH-05 | 729670 | 7659147 |
| MBH-06 | 730017 | 7658270 |

100 50 0 100 200 300
SCALE (METRES) 1:7,500 (A3)

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SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
GENERAL ARRANGEMENT PLAN

PE801-00300 M20002
Figure 5

## NOTES:

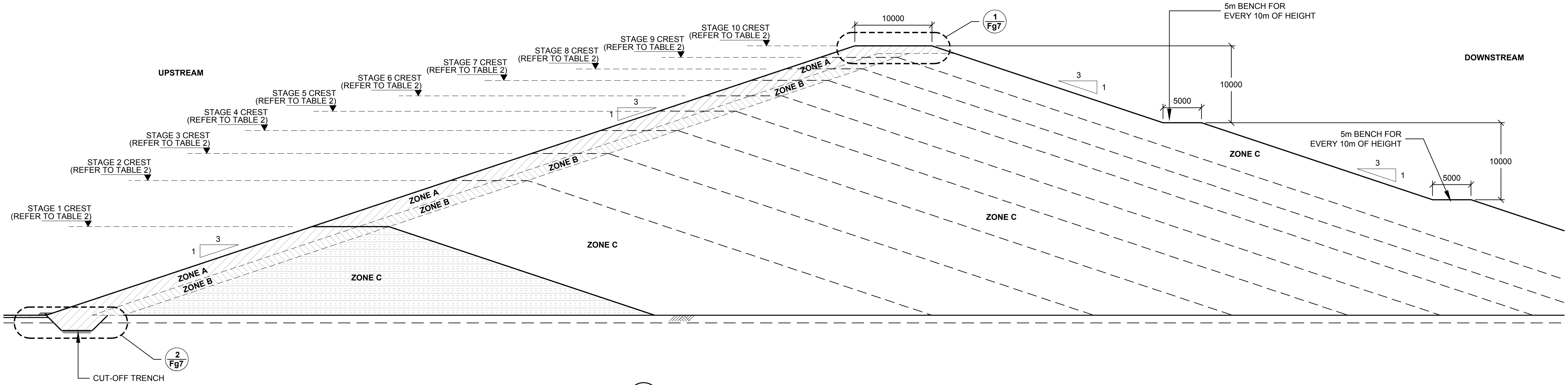
1. FOUNDATION PREPARATION SHALL EXTEND 5000mm BEYOND THE TOE OF THE EMBANKMENT.
2. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
3. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
4. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
5. CUT-OFF TRENCH MINIMUM DEPTH OF 1.5m BELOW GROUND LEVEL AND A MINIMUM OF 1m INTO WEATHERED ROCK.
6. SAFETY BERM MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.
7. FOR ZONE SPECIFICATIONS REFER TABLE 1.
8. FOR EMBANKMENT STAGE CREST ELEVATIONS REFER TABLE 2.

## TABLE 1: SOIL SPECIFICATIONS SUMMARY

| ZONE TYPE | DESCRIPTION | COMPACTION SPECIFICATION |
|---|---|---|
| ZONE A | LOW PERMEABILITY FILL - WIN FROM BORROW | 98% SMDD, -3%<OMC<+3% 300mm LAYERS |
| ZONE B | TRANSITION MATERIAL -WIN FROM BORROW / MINE WASTE | 98% SMDD, -3%<OMC<+3% 300mm LAYERS |
| ZONE C | STRUCTURAL FILL - OXIDE MINE WASTE/WIN FROM BORROW | 95% SMDD, -3%<OMC<+3% 500mm LAYERS |
| ZONE D | APPROVED GENERAL FILL | UNIFORM DENSITY FREE FROM CAVITIES |
| ZONE E | EROSION PROTECTION - COMPETENT WASTE ROCK | UNIFORM DENSITY FREE FROM LARGE CAVITIES |
| ZONE F | DRAINAGE MEDIUM - SAND OR FINE GRAVEL | UNIFORM DENSITY FREE FROM CAVITIES |
| ZONE G | SELECTED CLEAN ROCKFILL - NO FINES | UNIFORM DENSITY FREE FROM LARGE CAVITIES |
| RIPRAP | SELECTED ROCKFILL | UNIFORM DENSITY FREE FROM LARGE CAVITIES |
| EMBANKMENT FOUNDATION | IN-SITU MATERIAL AS APPROVED BY THE ENGINEER | WITHIN 5m OF THE CUT OFF TRENCH, 95% SMDD, -3%<OMC<+3% |
| CUT OFF TRENCH | LOW PERMEABILITY FILL (EQUIVALENT TO ZONE A) | 98% SMDD, -1%<OMC<+3% 300mm LAYERS |

## TABLE 2: EMBANKMENT CREST ELEVATION DETAILS

| EMBANKMENTS | NORTH MAIN EMBANKMENT | SOUTH MAIN EMBANKMENT | NORTH-WEST SADDLE EMBANKMENT | WEST SADDLE EMBANKMENT | TOTAL STORAGE CAPACITY |
|---|---|---|---|---|---|
| STAGE | ELEVATION (m R.L.) | ELEVATION (m R.L.) | ELEVATION (m R.L.) | ELEVATION (m R.L.) | Mt. |
| 1 | 1337.0 | 1337.0 | - | - | 1.135 |
| 2 | 1343.0 | 1343.0 | - | - | 2.27 |
| 3 | 1346.5 | 1346.5 | - | - | 3.35 |
| 4 | 1349.5 | 1349.5 | - | - | 4.375 |
| 5 | 1352.0 | 1352.0 | - | - | 5.4 |
| 6 | 1354.0 | 1354.0 | - | - | 6.425 |
| 7 | 1356.0 | 1356.0 | - | - | 7.45 |
| 8 | 1357.5 | 1357.5 | - | - | 8.475 |
| 9 | 1359.0 | 1359.0 | 1358.0 | 1356.0 | 9.5 |
| 10 | 1360.5 | 1360.5 | 1359.5 | 1358.0 | 10.53 |

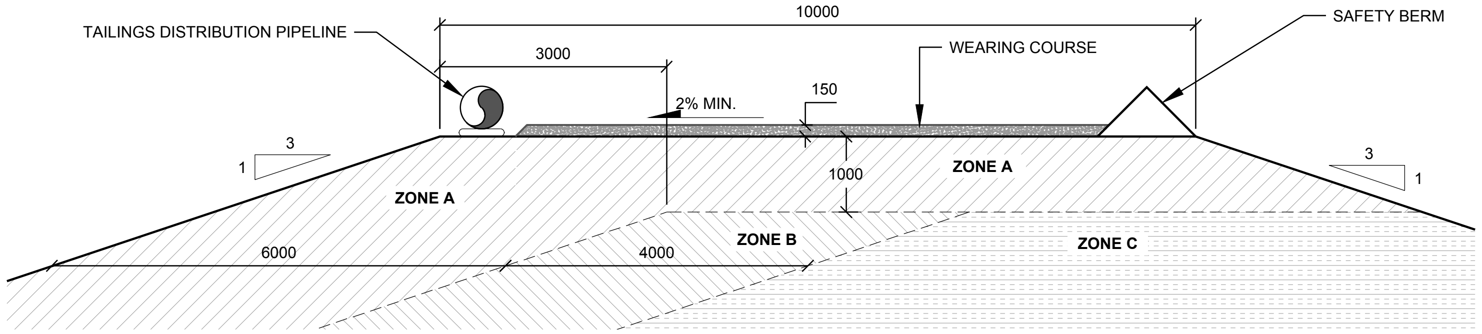



A Fg5 **TYPICAL FINAL EMBANKMENT SECTION**

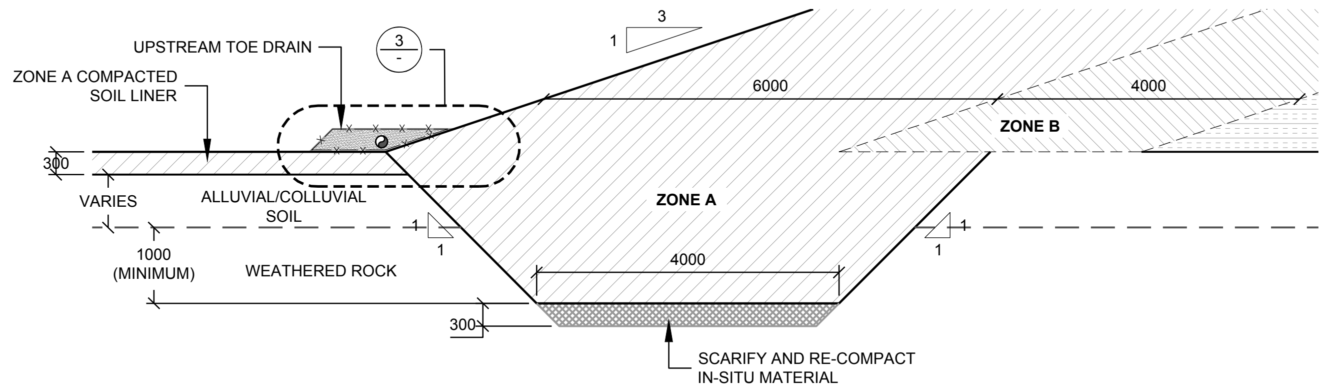
1:500

## NOTES:

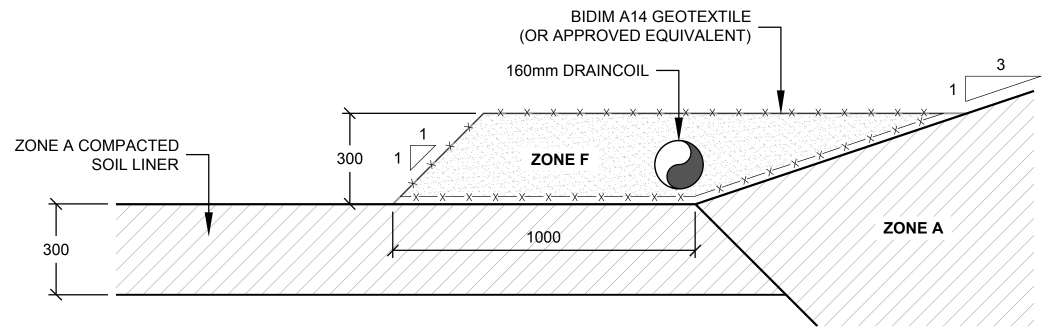
1. FOUNDATION PREPARATION SHALL EXTEND 5000mm BEYOND THE TOE OF THE EMBANKMENT.
2. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
3. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
4. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
5. CUT-OFF TRENCH MINIMUM DEPTH OF 1.5m BELOW GROUND LEVEL AND A MINIMUM OF 1m INTO WEATHERED ROCK.
6. SAFETY BERM MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.
7. FOR ZONE SPECIFICATIONS REFER TABLE 1, ON FIGURE 6.
8. FOR EMBANKMENT STAGE CREST ELEVATIONS REFER TABLE 2, ON FIGURE 6.




1 Fg6 **TYPICAL EMBANKMENT CREST DETAIL**
1:100




2 Fg6 **TYPICAL CUT-OFF TRENCH DETAIL**
1:100




3 - **TYPICAL UPSTREAM TOE DRAIN DETAIL**
1:25

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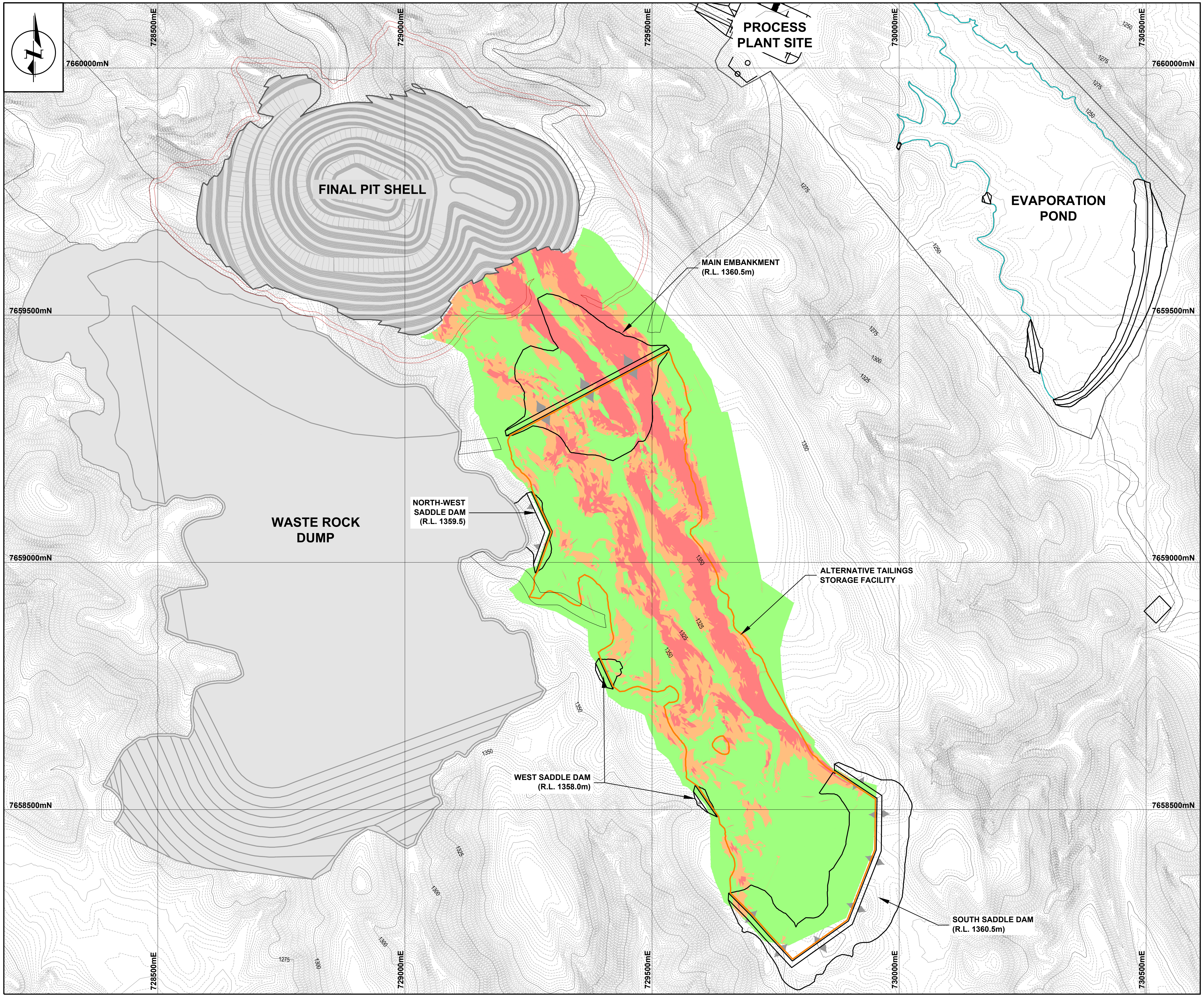
ALTERNATIVE TAILINGS STORAGE FACILITY
EMBANKMENT SECTIONS AND DETAILS - SHEET 2

PE801-00300 M20002
Figure 7




## NOTES:

1. 5m CONTOUR INTERVAL SHOWN. 2m CONTOUR INTERVAL TOPOGRAPHIC DATA PROVIDED BY VENTUREX RESOURCES LIMITED, AUGUST 2018.
2. PLANT SITE LAYOUT PROVIDED BY VENTUREX RESOURCES LIMITED, MARCH 2018.
3. WASTE DUMP LAYOUT PROVIDED BY VENTUREX RESOURCES LIMITED, SEPTEMBER 2018.
4. PIT SHELL AND PIT ABANDONMENT BUND PROVIDED BY VENTUREX RESOURCES LIMITED, AUGUST 2018.

## LEGEND:

- PIT ABANDONMENT BUND
- EXISTING GROUND SLOPE ≤ 1(V) : 3(H)
- EXISTING GROUND SLOPE ≥ 1(V) : 3(H) ≤ 1(V) : 2(H)
- EXISTING GROUND SLOPE ≥ 1(V) : 2(H)

100 50 0 100 200 300
SCALE (METRES) 1:7,500 (A3)

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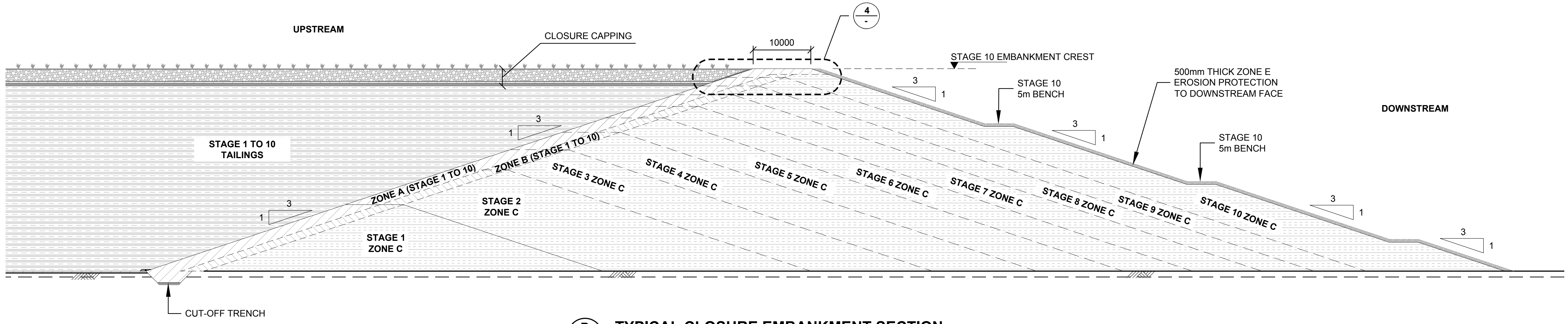
ALTERNATIVE TAILINGS STORAGE FACILITY
EXISTING GROUND SLOPES

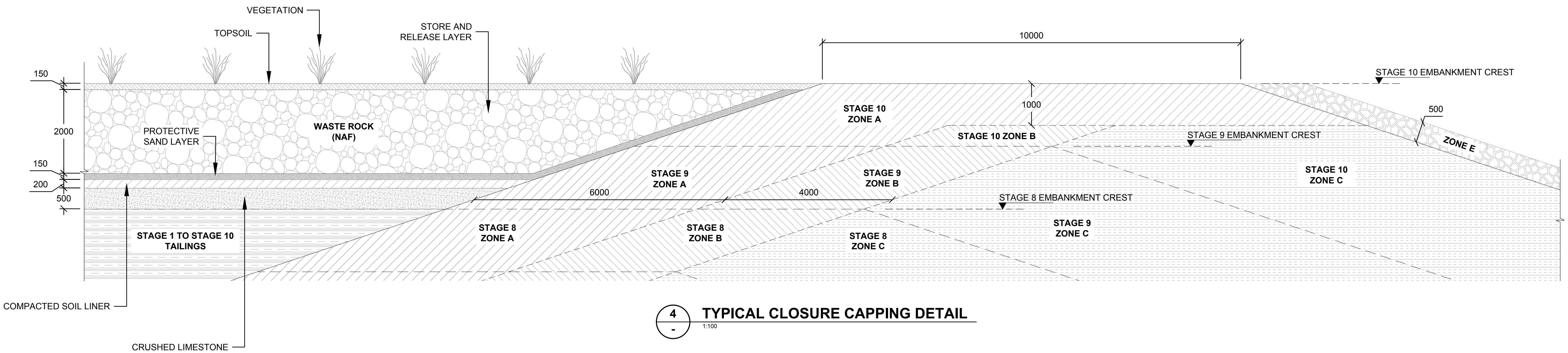
PE801-00300 M20002
Figure 8

## NOTES:

1. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
2. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
3. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
4. SAFETY BERM MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.




**B** / - **TYPICAL CLOSURE EMBANKMENT SECTION**
1:500




**4** / - **TYPICAL CLOSURE CAPPING DETAIL**
1:100