Robe River Mining Co. Pty Ltd ABN: 71 008 694 246

# West Angelas Closure Plan

April 2018

Mineral Field 47 – West Pilbara FDMS No RTIO-HSE-0228290

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# EXECUTIVE SUMMARY

#### Overview

West Angelas is an open cut iron ore mine located in the Eastern Pilbara region of Western Australia, approximately 105 km north-west of Newman. The mine uses conventional drill-and-blast and load-and-haul mining methods to remove iron ore from above and below the water table.

### Scope

This closure plan covers currently approved deposits and associated infrastructure at West Angelas (Deposits A, A West, B, E and F) and the proposed C, D and G deposits that have been referred to the Environmental Protection Authority (EPA) for environmental approval. It is an update of the February 2015 version of the West Angelas closure plan, and will supersede that document once it has been formally accepted.

The closure plan has been developed to meet the requirements of the Rio Tinto Closure Standard and the joint Department of Mines and Petroleum (DMP) and EPA *Guidelines for Preparing Mine Closure Plans* (May 2015).

#### Post-mining land use

As West Angelas is underlain by Vacant Crown Land, and is located in close proximity to Karijini National Park, the return of a native ecosystem is considered to be the most appropriate final land use. This is consistent with advice provided by the OEPA in November 2014.

#### Closure objectives

The following closure objectives have been set for the site:

- Final landform is stable and considers ecological and hydrological issues;
- Vegetation on rehabilitated land is self-sustaining and compatible with the final land use;
- Public safety hazards have been managed;
- Contamination risks have been appropriately managed;
- Infrastructure has been appropriately managed; and,
- Environmental (ecohydrological) values of the potential groundwater dependant ecosystem are maintained.

These objectives have evolved from those in the approved May 2015 plan.

## Anticipated closure outcome

The shape of the landscape at West Angelas is still evolving, with the final mine void areas and waste dump locations and dimensions still in development across all of the deposits.

Mine voids will be backfilled to prevent the formation of permanent pit lakes, although water may temporarily pool at the base of the voids following heavy rainfall. The proposal to develop Deposits C, D and G assumes water levels beneath a potentially groundwater dependent ecosystem at Karijini National Park will be lowered between 1 to 6 metres over a 100 year post-mining timeframe. The Closure plan does not currently consider reinstating the pre-mining groundwater levels post mining as the proposed operational and closure strategies are considered adequate to maintain the values of Karijini National Park. The area around pit voids may be unstable as pit walls are expected to collapse over time, and inadvertent access will be restricted by the use of physical barriers (e.g. abandonment bunds).

Waste dumps will be reshaped so as to be stable, and all disturbed areas except pit voids will be rehabilitated with native vegetation with the aim of creating self-sustaining ecosystems that function in a similar fashion to those present in the pre-mining environment.

It is assumed that all infrastructure will be removed, but this will be subject to negotiation with the Western Australian State Government as per State Agreement obligations. Creek diversions have been designed to be permanent structures, and there are no plans to reinstate original surface water flow paths.

# **CLOSURE PLAN CHECKLIST**

The following table provides cross reference to the requirements of the Department of Mines and Petroleum / Environmental Protection Authority *Guidelines for preparing mine closure plans* (2015).

	Mine Closure Plan (MCP) Checklist	Y/N /NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
1	Has the Checklist been endorsed by a senior representative within the operating company?	Y	-		-		
Publi	c Availability						
2	Are you aware that from 2015 all MCPs will be made publically available?	Y	-				
3	Is there any information in this MCP that should not be publicly available?	Y	-	Appendix C is considered confidential			
4	If "Yes" to Q3, has confidential information been submitted in a separate document / section?	Y	-				
Cove	r page, table of contents						
5	Does the MCP cover page include: Project Title, Company Name, Contact Details (including telephone numbers and email address) Document ID and version number, Date of submission (needs to match the date of this checklist)	Y	-		-		
Scop	e 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 requirement)	-	-	Support Part IV referral of Deposit C/D/G	-		
Proje	ect overview						
7	Does the project summary include land ownership details, location of the project, comprehensive site plans and background information on the history and status of the project?	Y	3		N		
Lega	l obligations and commitments						
8	Does the MCP include a consolidated summary or register of closure obligations and commitments been included?	Y	Appendix A		N		

	Mine Closure Plan (MCP) Checklist	Y/N /NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
Stake	eholder engagement						
9	Have all stakeholders involved in closure been identified?	Y	5		N		
10	Does the MCP included a summary or register of historic stakeholder engagement been provided, with details on who has been consulted and the outcomes?	Y	Appendix B		Y		Update with consultation undertaken to support Part IV referral
11	Does the MCP include a stakeholder consultation strategy to be implemented in the future?	Y	25		N		
Post	mining land use(s) and closure objective	S					
12	Does the MCP include agreed post- mining land use, closure objectives and conceptual landform design diagram?	Y	26		Y	26	Changes from last version explain in Section 7.2
13	Does the MCP identify all potential (or pre-existing) environmental legacies which may restrict the post mining land use (including contaminated sites)?	Y	14		Ν		
14	Has any soil or groundwater contamination that occurred, or is suspected to have occurred, during the operation of the mine, been reported to DER as required under the Contaminated Sites Act 2003?	N	-		N		
Deve	elopment of completion criteria						
15	Does the MCP include an appropriate set of specific completion criteria and closure performance indicators?	Y	28		Y	31	Changes explained in Section 8.1
Colle	ection and analysis of closure data						
16	Does the MCP include baseline data (including pre-mining studies and environmental data)	Y	33	Also Appendix C	Y	-	Information updated to incorporate discussion on Deposit C,D and G where relevant

	Mine Closure Plan (MCP) Checklist	Y/N /NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
17	Has materials characterisation been carried out consistent with applicable standards and guidelines (e.g. GARD Guide)?	Y	39		N		
18	Does the MCP identify applicable closure learnings from benchmarking against other comparable mine sites?	Ν	-	Information learnt from other sites (particularly other Pilbara mines managed by Rio Tinto) is incorporated into the closure plan, but there has been no formal benchmarking exercise	N		
19	Does the MCP identify all key issues impacting mine closure objectives and outcomes (including potential contamination impacts)?	Y	Appendix D		Y		Closure risk assessment updated to incorporate Deposits C D and G
20	Does the MCP include information relevant to mine closure for each domain or feature?	Y	Appendix E		Y		Updated to incorporate Deposits C D and G
Ident	ification and management of closure issu	ies	1		1		1
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	76	Risk assessment and gap analysis is based on issues management rather than specific domains	Y	76	Updated to consider Deposits C D and G.
22	Does the MCP include the process, methodology and has the rationale been provided to justify identification and management of the issues?	Y	65		N		
Closu	ure Implementation						
23	Does the MCP include a summary of closure implementation strategies	Y	78		Y	78	Updated to consider

	Mine Closure Plan (MCP) Checklist	Y/N /NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
	and activities for the proposed operations or for the whole site?						Deposits C D and G.
24	Does the MCP include a closure work program for each domain or feature?	Y	78		N		
25	Does the MCP contain site layout plans to clearly show each type of disturbance as defined in Schedule 1 of the MRF Regulations?	Y	78		Y	78	Updated to consider Deposits C D and G.
26	Does the MCP contain a schedule of research and trial activities?	Y	76		Y	76	Table of actions was not included in previous closure plan
27	Does the MCP contain a schedule of progressive rehabilitation activities?	N		Progressive rehabilitation will be conducted when areas become available			
28	Does the MCP include details of how unexpected closure and care and maintenance will be handled?	Y	82		N		
29	Does the MCP contain a schedule of decommissioning activities?	N		This will be developed as the site approaches closure			
30	Does the MCP contain a schedule of closure performance monitoring and maintenance activities?	Y	83	Indicative monitoring program. The program will be further developed as the site approaches closure			
Closu	ure monitoring and maintenance	1				1	
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	83				

	Mine Closure Plan (MCP) Checklist	Y/N /NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
Finar	cial provisioning for closure						
32	Does the MCP include costing methodology, assumptions and financial provision to resource closure implementation and monitoring?	Y	85				
33	Does the MCP include a process for regular review of the financial provision?	Y	85				
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	87				

#### Corporate endorsement:

I hereby certify that to the best of my knowledge, the information within this Mine Closure Plan is true and correct and addresses the relevant requirements of the *Guidelines for Preparing Mine Closure Plans* approved by the Director General of Mines and Petroleum.

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General Manager - Orebody Knowledge and Planning

Date: 11/04/2018

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# SCOPE AND PURPOSE

# 1. Purpose

Planning for closure of a site is a critical business process that demonstrates Rio Tinto's commitment to sustainable development. This closure plan has been prepared in accordance with the Department of Mines and Petroleum (DMP) / Environmental Protection Authority (EPA) *Guidelines for preparing mine closure plans* (2015).

This closure plan has been updated to achieve the following goals:

- support environmental impact assessment of West Angelas Deposits C, D and G;
- approval of the closure plan during the course of Part IV assessment of the Deposit C, D and G project;
- submission to the Department of State Development, to satisfy a request from that Department;
- submission to the Office of the EPA for approval under condition 9 of Ministerial Statement 970 issued in relation to the West Angelas Iron Ore Project (this submission will occur following confirmation that environmental approval of Deposits C, D and G has been granted);
- meet the internal requirements of the Rio Tinto Closure Standard (2015) mandated for all Rio Tinto businesses;
- reflect the current knowledge and requirements for closure of West Angelas mine and identify the future requirements to continue to progress towards a planned and managed closure of the site; and
- inform the development of closure provisions.

# 2. Scope

This plan covers development of Deposits A, A West, B, C, D, E, F and G, and applies to the following:

- Mine development within the following leases<sup>1</sup>;
  - ML248SA Sections 067-084 (mining lease issued pursuant to the Robe River State Agreement)
  - o G47/01235;
  - o G47/01236;
  - o L47/41 (Turee B borefield);
  - o L47/52 (road);
  - o L47/53 (road);
  - L47/54 (gas pipeline);
  - L47/61 (repeater station);
  - L47/62 (repeater station);
  - o L47/63 (rail);
  - o L52/75 (gas pipeline)

The plan excludes the following:

- potential future expansions at West Angelas or the surrounding area; and
- the mainline rail.

This closure plan supersedes all previous closure, and decommissioning and rehabilitation plans for West Angelas.

<sup>&</sup>lt;sup>1</sup> Note that the scope of the closure plan has been aligned to tenure boundaries, which may differ from the footprint approved or referred under Part IV of the *Environmental Protection Act 1986*.

# 2.1 Closure Planning Process

Closure planning is an iterative process that commences during the planning phase of the mine development and is regularly updated and refined during the operational phase (Figure 1). Closure plans are updated to account for changes resulting from:

- amendments to the mine plan;
- improvements of the site closure knowledge base (eg. through daily activities, technical studies and research actions, progressive rehabilitation);
- new or amended regulation;
- changes to surrounding land uses; and
- evolving stakeholder expectations.

The review brings specialists together to discuss current performance, proposed mine changes and opportunities to improve closure outcomes. At the end of the review, improvement actions are assigned and the closure plan is updated.

A key output of closure planning is the development of a closure cost estimate. Closure provisions are subsequently integrated into our business planning processes to ensure funds will be available to close the site effectively.

The detail of each closure plan increases as the knowledge base develops. When the site approaches scheduled closure, studies will be completed to define how infrastructure, decontamination, rehabilitation, the workforce and communications will be managed throughout the mine closure period (and beyond). Stakeholder engagement and endorsement of completion criteria is conducted at this time.

In the final closure plan, location specific management plans are provided for each closure domain. These detailed plans cover the physical closure, dismantling and subsequent rehabilitation implementation requirements. The supporting technical reports that have been used to predict the post-closure outcomes are appended to the final closure plan.



Figure 1: Progression of closure planning<sup>2</sup>

<sup>&</sup>lt;sup>2</sup> Rio Tinto Closure Guidance 2015 (Adapted from ICMM 2008)

# PROJECT OVERVIEW

# 3. Description of the operation

# 3.1 Location

West Angelas is located in the Pilbara region of Western Australia, approximately 105 km north-west of Newman, and falls within the local authority of the Shire of East Pilbara. It is in a relatively remote region of the State, with the closest town being Newman (Figure 2). There are no other communities in the immediate vicinity. Tenure associated with current and proposed mining activities is shown in Figure 3.

The mine is located predominantly on the traditional lands of the Yinhawangka people, with the eastern portion of Deposit F located on land held by the Ngarlawangga people (Figure 3). The nearest Aboriginal communities are Bellary and Wakathuni, which are both located on Yinhawangka land and are 80 km and 100km respectively to the west.

The West Angelas mining lease has been issued on unallocated crown land. There is no pastoral activity in the immediate vicinity of the mine, with the nearest pastoral station lease (Juna Downs) approximately 20 km to the north. Juna Downs is operated by Hamersley Iron Pty Ltd, which is wholly owned by Rio Tinto.

West Angelas mine is operated by the Rio Tinto iron ore group (Rio Tinto), on behalf of the Robe River Mining joint venture (JV) of whom Rio Tinto is the largest shareholder. The Robe River Mining JV comprises:

- Rio Tinto (53%);
- Mitsui Iron Ore Development Pty Ltd (33%);
- Pannawonica Iron Associates (10.5%); and
- Cape Lambert Iron Associates (3.5%).

# 3.2 Mine Operations

The West Angelas mine commenced operations in 2001. It is an open cut operation utilising conventional drilland-blast and load and haul mining methods. The currently approved layout is presented in Figure 4, and consists of five deposits (A, A West, B, E and F). Approval is being sought for a further three deposits (C, D and G).

Mine planning schedules are currently being revised to incorporate the proposed new deposits. Several scenarios are still under evaluation, each of which would result in changes to the projected commencement and cessation dates of various deposits. The current central case scenario is presented in Table 1 below, but should be considered indicative only. The mine schedules and plans are subject to regular review to ensure optimised performance of the operations and are therefore subject to change.

It should be noted that there is the potential for further ongoing development of additional West Angelas deposits subject to future approval. Should these exploration areas eventually get developed, mining at West Angelas would continue longer than indicated in Table 1. The addition of new deposits may also impact the mining sequence and schedules for currently approved or proposed deposits.

The key landforms associated with the mine are shown in Table 2 below. The proposed construction and rehabilitation design criteria for these landforms are included in Appendix E.

Table 1: Indicative mining schedule	(current central case, but c	nlv one of several developme	nt scenarios under evaluation)
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Deposit	Pit	Commencement	Completion	Description	Regulatory Status
A	A	Commenced	2022	BWT	Approved
A West	3 pits anticipated	2027	2036	Mostly AWT	Approved
В	В	Commenced	2023	Mostly AWT	Approved
С	C1, C2 and C3	2020	2028	BWT	Proposed
D	D1, D2 and D3	2020	2030	BWT	Proposed
E	E	Commenced	2034	BWT	Approved
F	F1, F2 and F3	2016	2025	Mostly AWT	Approved
G	Multiple pits	2022	2027	Mostly AWT	Proposed

### Table 2: Waste landform inventory

Landform	Туре	Description	Status
Deposit A South WD	Waste Dump	Inert	Active / Partially Rehabilitated
Deposit A North WD	Waste Dump	Fibrous	Active / Partially Rehabilitated
Deposit A West Pit North Backfill	Backfilled pit area (treated as a waste dump)	Inert	Active
Deposit B East WD	Waste Dump	Fibrous	Active
Deposit B Low Grade	Low grade stockpile (treated as a waste dump)	Inert	Proposed
Deposit C&D WD1 West	Waste Dump	Inert	Conceptual
Deposit C&D WD1 East	Waste Dump	Inert	Conceptual
Deposit D WD	Waste Dump	Inert	Conceptual
Deposit E East WD	Waste Dump	Inert	Active (will be consumed by Deposit F West WD)
Deposit E South WD	Waste Dump	Inert	Active
Deposit E West WD	Waste Dump	Inert	Active
Deposit F West WD	Waste Dump	Inert	Proposed
Deposit F Low Grade	Low grade stockpile (treated as a waste dump)	Inert	Proposed
Deposit F East WD	Waste Dump	Inert	Proposed



Figure 2: Regional setting



Figure 3: Tenure and Native Title claim boundaries



Figure 4: West Angelas Mine Layout

# **IDENTIFICATION OF CLOSURE OBLIGATIONS AND COMMITMENTS**

# 4. Legal obligations

A closure obligations register is presented as Appendix A, It contains details of legal obligations from the following instruments:

- Iron Ore (Robe River) Agreement Act 1964;
- Ministerial Statement 970 (West Angelas Iron Ore Project) and Ministerial Statement 1015 (West Angelas Deposit A west and Deposit F).
- relevant Native Vegetation Clearing Permits (NCVP); and
- leases issued under the *Mining Act 1978*.

The register also identifies legislation, standards and guidelines that may not apply to West Angelas specifically, but that may be relevant to closure of mine sites generally.

# STAKEHOLDER ENGAGEMENT

# 5. Stakeholder engagement

# 5.1 Engagement process

Stakeholder engagement is a key part of mine closure planning as it ensures that the expectations of stakeholders are understood by the mine operator and these can be considered and managed during the planning and implementation phase of closure. Rio Tinto has established processes for consultation with stakeholders, and these are imbedded in both the Rio Tinto *Mine closure standard* (2015) and *Community and social performance standard* (2015). These standards are aligned with principles from the Australian and New Zealand Minerals and Energy Council and the Minerals Council of Australia (ANZMEC/MCA, 2000). Consultation commences at appropriate times during the early stages of exploration planning and will continue until the final relinquishment of the site.

As part of this process all stakeholders that are relevant to the mining operations are identified and recorded in a register. This register is used to ensure relevant and timely communications are held with stakeholders across a broad range of issues, including closure. This register is regularly reviewed and updated to maintain currency. Regular consultation is conducted with a wide range of stakeholders via a variety of forums, for example various State and Local Government agency briefing meetings and Traditional Owner consultation forums established under Indigenous Land Use Agreements. Discussions regarding closure and related activities are included in these meetings as appropriate. The level of closure specific content and detail will increase as closure approaches.

A communications register specifically for closure of West Angelas is maintained and a copy as at the time of writing is included in Appendix B. This register is used to ensure stakeholder feedback is tracked and monitored to ensure that appropriate actions are taken to address these issues in a timely manner.

# POST-MINING LAND USE AND CLOSURE OBJECTIVES

# 6. Post-mining land use

# 6.1 Historical land use

Aside from mining activity and associated infrastructure, the West Angelas area is largely undeveloped. Pastoral activity in the region has historically been limited to grazing of cattle on Juna Downs Station to the north (the most southern boundary of which is located approximately 20 km to the north) and Rocklea Station (approximately 75 km to the west). There are no other mines currently operating in the immediate vicinity.

# 6.2 **Proposed post-mining land use**

Options for post-mining land use are limited in the Pilbara region, with mining and pastoralism the only industries that have historically proven viable. Inland regions are sparsely populated, with the largest inland towns (such as Tom Price, Paraburdoo and Newman) established specifically to support the mining industry. Beneficial uses for the mining area (e.g. recreation or aquaculture) that might have potential in areas supported with a higher population base are unlikely to be viable.

As West Angelas is underlain by Vacant Crown Land, and is located in close proximity to Karijini National Park, the return of a native ecosystem is considered to be the most appropriate final land use. This is consistent with advice provided by the OEPA in November 2014.

# 7. Closure objectives

## 7.1 **Rio Tinto vision for closure in the Pilbara**

Closure objectives have been developed with consideration of Rio Tinto's general vision for closure, which is to:

- Relinquish its mining leases to the Western Australian State Government.
- Preserve, protect and manage the cultural heritage values of the area in cooperation with the Traditional Owners and other stakeholders.
- Develop and implement strategies for closure which consider the implications on local communities.
- Achieve completion criteria which have been developed with stakeholders and agreed with WA Government.
- Develop landforms that are safe and stable and compatible with the surrounding environment and postmining land use.
- Achieve environmental outcomes that are compatible with the surrounding environment.
- Implement a workforce strategy which addresses the impacts of closure on employees and contractors.
- Achieve successful closure in a cost effective manner.

## 7.2 West Angelas closure objectives

The ultimate goal of mine closure at West Angelas is to relinquish the site to the Government. This goal will be achieved once the government and community agree that the condition of the site is compatible with an agreed post-mining land use. Closure objectives reflect the aspects of the closure plan that the government and community agree are key to evaluating the site condition.

The approved February 2015 West Angelas closure plan included the objectives contained in Table 3. Whilst the intent of the February 2015 objectives remains current with the introduction of Deposits C, D and G into the closure plan scope, some revisions have been made to more explicitly address several key issues. The revised objectives are presented in Table 4.

#### Table 3: West Angelas closure objectives (February 2015 closure plan)

No.	February 2015 closure objective (now obsolete)
1	Rehabilitated landforms are stable
2	Final landforms are rehabilitated to be compatible with the final land use
3	Changes to surface water flows or groundwater quality are within acceptable limits
4	Public safety hazards have been addressed

Table 4: Revised West Angelas closure objectives (June 2017 closure plan)

No.	Revised (current) closure objective	Justification for change
1	Final landform is stable and considers ecological and hydrological issues	This new objective covers the issues addressed by previous objectives 1 and 3, and aligns with objectives for other Rio Tinto mines
2	Vegetation on rehabilitated land is self-sustaining and compatible with the final land use	Explicit recognition that rehabilitation areas need to be self-sustaining
3	Public safety hazards have been managed	It will not necessarily be possible to completely eliminate risk, but the company needs to demonstrate that risks have been effectively managed
4	Contamination risks have been appropriately managed	New objective to recognise this closure issue
5	Infrastructure has been appropriately managed	New objective to recognise this closure issue
6	Environmental (ecohydrological) values of the potential groundwater dependant ecosystem are maintained	This new objective recognises the potential groundwater dependant ecosystem as a sensitive receptor for the Deposit C and D proposal.

Note that these objectives do not represent the full range of issues that need to be addressed upon closure of West Angelas: rather they represent the key objectives against which the ability to relinquish will be assessed.

Indicative completion criteria and measurement tools have been drafted for each of these objectives, and are discussed further in Section 8.

# **COMPLETION CRITERIA**

# 8. Completion criteria

Completion criteria are defined as the indicators used to determine whether closure objectives have been met. They are used to measure the success of closure implementation against objectives, and to facilitate relinquishment of mining tenure.

The completion criteria (Table 5) have been developed in consideration of the predicted closure outcomes. Measurement processes, and the associated supporting data (evidence and / or metrics), that could be used to evaluate the success of closure at West Angelas are also described in Table 5.

The completion criteria are subject to ongoing review and update, informed by the outcome from studies, monitoring and ongoing stakeholder consultation. Given the number of years until scheduled closure the completion criteria contained in this plan should be considered indicative only. As the site approaches scheduled closure the completion criteria will contain more measurable and time-bound parameters.

0	ojective	Indicative completion criteria	Verification process or method Evidence
1.	Final landform is stable and considers ecological and hydrological issues	ndform is stable and considers cal and hydrological issues1.There are no erosion features present that compromise landform integrity, and erosion features (if present) are stable1.Visual assessment and monitoring including quantitative evaluation of rills and gullies, with evaluation of trends over time	<ol> <li>Visual assessment and monitoring including quantitative evaluation of rills and gullies, with evaluation of trends over time</li> <li>Rehabilitation monitoring reports</li> <li>Post-closure landform evaluation report</li> <li>Survey data assessment</li> </ol>
		<ol> <li>Unless otherwise approved, waste dumps are located outside of the zone of geotechnical instability around pits</li> </ol>	<ol> <li>Analysis of aerial imagery to provide qualitative/quantitative analysis of landform stability</li> </ol>
		<ol> <li>The final landform has been constructed with consideration given to its stability during intense rainfall and large flood events</li> </ol>	<ol> <li>Post-closure landform review to confirm that risks have been appropriately mitigated</li> </ol>
		<ol> <li>Erosion from landforms does not threaten the functionality of natural ecosystems</li> </ol>	
		<ol> <li>Landform design (including design of surface water diversions) and final landscaping considers local and off- site hydrological impacts</li> </ol>	
2.	Vegetation on rehabilitated land is self- sustaining and compatible with the final	<ol> <li>Seed used in rehabilitation works is of local provenance</li> </ol>	<ol> <li>Rehabilitation monitoring program</li> <li>Rehabilitation monitoring reports</li> <li>Analysis of historical monitoring data</li> </ol>
	land use	<ol> <li>Native plants within rehabilitated areas are observed to flower and/or fruit</li> </ol>	
		3. Recruitment of native perennial plants is observed	
		<ol> <li>Any weeds recorded within rehabilitation areas are consistent with those from the local area</li> </ol>	
		5. Species richness and diversity are indicative of a functional ecosystem	

#### West Angelas Closure Plan

3.	Public safety hazards have been managed	1. 2.	Safety and health risks have been identified Measures to mitigate the identified public safety and health hazards have been agreed with stakeholders, and have been implemented	1. 2. 3.	Risk assessment conducted and mitigation actions implemented Key stakeholders have been engaged and there is agreement on risk mitigation measures to be employed Independent audit/review to confirm that agreed hazard mitigation measures have been implemented	1. 2. 3. 4.	Risk assessment report Records of stakeholder engagement Agreed risk mitigation actions Audit/review report
4.	Contamination risks have been appropriately managed	1.	Requirements of the <i>Contaminated</i> <i>Sites Act 2003</i> have been met for the identification, remediation, management and transfer of any contaminated sites	1. 2. 3.	The site has been appropriately assessed for the presence of suspected or known contaminated sites Suspected or known contaminated sites have been appropriately reported under the requirements of the <i>Contaminated Sites Act 2003</i> Appropriate management measures to address contamination have been implemented	1. 2.	Contaminated sites investigation reports Reports on any ongoing monitoring, management and/or remediation of contaminated sites
5.	Infrastructure has been appropriately managed	1. 2.	Legal agreement to transfer residual liability completed (if required) Where transfer of liability is not established, infrastructure has been decommissioned and removed	1. 2.	Appropriate agreements and transfer processes are in place and communicated for any infrastructure remaining post-closure Removal of all infrastructure that has not been agreed to remain	1. 2. 3.	Agreements in place with party assuming liability for infrastructure Decommissioning report Visual inspection
6.	Environmental (ecohydrological) values of the potential groundwater dependant ecosystem are maintained	1. 2. 3.	Surface water diversions are maintained at closure in an appropriate capacity Pits are backfilled to a level that prevents the formation of permanent pit lakes Vegetation of potential groundwater dependant ecosystem reflects baseline data	1.	Modelling and engineering specifications/designs confirmed in the final landform Monitoring and assessment of ecosystem in comparison of baseline data	1. 2. 3.	Post closure landform evaluation report Vegetation and ecosystem monitoring reports Agreement of stakeholders

# 8.1 Changes to completion criteria from the last closure plan

Rio Tinto has been continually refining its approach to establishing and presenting completion criteria for the past several years, and expects this process to continue in the future. In addition, the OEPA requested several specific changes to the completion criteria when it approved the February 2015 West Angelas closure plan in July 2106.

The completion criteria table has been substantively revised since February 2015.

## 8.1.1 Objective 1

The new objective has been redrafted so as to address issues relevant to the previous objectives 1 and 3. New criteria have been developed for the reasons stated in Table 6.

Table 6: Explanation for changes to criteria for Objective 1

Criterion in February 2015 closure plan (objectives 1 &3)	New criterion in June 2017 closure plan	Explanation for change
Demonstration that rills and gullies are stable	There are no erosion features present that compromise landform integrity, and erosion features (if present) are stable	The revised wording makes the intent of this criterion clearer
AMD risks are appropriately identified and managed	Removed	There is a low risk of AMD at West Angelas, and the issue is adequately addressed in the new objective on management of contamination risks
There are no unapproved changes to surface water flow regimes	Landform design (including design of surface water diversions) and final landscaping considers local and off-site hydrological impacts	The Pilbara is a dynamic environment and surface water flow regimes can change naturally following intense events. Furthermore, the old criterion required drainage changes to be approved, even though there are no approval mechanisms available for minor and trivial local changes.
-	Waste dumps are located outside of the zone of geotechnical instability around pits	New criterion to recognise this closure risk. Rio Tinto recognises that several West Angelas waste dumps are located in close proximity to pits and that any approval to retain them would require justification based on the geotechnical risk profile of each specific location.
-	The final landform has been constructed with consideration given to its stability during intense rainfall and large flood events	New criterion to recognise this closure risk
-	Erosion from landforms does not threaten the functionality of natural ecosystems	New criterion to recognise this closure risk

#### 8.1.2 Objective 2

Changes to criterion for this objective are explained in Table 7.

Table 7: Explanation for changes to criteria for Objective 2

Criterion in February 2015 closure plan	New criterion in June 2017 closure plan	Explanation for change
Vegetation is similar to the natural environment	Seed used in rehabilitation works is of local provenance	The previous criterion was not sufficiently specific.
Weed species are not unduly prevalent on rehabilitated areas	Any weeds recorded within rehabilitation areas are consistent with those from the local area	The criterion has been revised to recognise that it is unrealistic to expect rehabilitated areas to remain free of weed species if they are present in the surrounding landscape. The new criterion provides a more objective basis for determining whether weeds are unduly prevalent (i.e. comparison with the surrounding landscape)
Habitat is present for a variety of fauna species	Species richness and diversity are indicative of a functional ecosystem	The goal of rehabilitation will be to create functional ecosystems with a range of species present. Whilst there will be no guarantee of faunal colonisation, 'species richness and diversity' would include faunal species, and rehabilitation monitoring includes their identification (e.g. presence of tracks and scats, presence of ants).
-	Native plants within rehabilitated areas are observed to flower and/or fruit	This criterion has been drafted to address the requirement for vegetation communities on rehabilitated areas to be self-sustaining.
-	Recruitment of native perennial plants is observed	This criterion has been drafted to address the requirement for vegetation communities on rehabilitated areas to be self-sustaining.

## 8.1.3 Objective 3

Changes to criterion for this objective are explained in Table 8.

Table 8: Explanation for changes to criteria for Objective 3

Criterion in February 2015 closure plan	New criterion in June 2017 closure plan	Explanation for change
-	Safety and health risks have been identified	New criterion to ensure that a risk identification process has been undertaken.
Public safety hazards have been addressed	Measures to mitigate the identified public safety and health hazards have been agreed with stakeholders, and have been implemented	The new criterion provides a more objective basis for determining that the outcome has been met. It is noted that it is unrealistic for associated risks to be completely eliminated. The new criterion allows for some level of residual risk, but ensures that this level is established through stakeholder negotiation.

## 8.1.4 Objectives 4 and 5

Criteria have been set for these new objectives to align with closure plans of other Rio Tinto sites.

#### 8.1.5 Objective 6

Criteria have been set for this new objective to recognise the potential groundwater dependant ecosystem as sensitive receptor of Deposit C and D.

# COLLECTION AND ANALYSIS OF CLOSURE DATA

The closure knowledge database (Appendix C) is a collection of baseline studies, models and interpretations, which are used to inform the closure planning process presented in this closure plan. The knowledge may be specific to the site or generally applicable to the Pilbara region; and includes information on the performance of closure-related trials completed at other Pilbara mining operations (when appropriate).

# 9. Climate

The closest official Bureau of Meteorology weather recording station is at Newman Aerodrome (station 007176). Climatic information has been captured from this site since 1971. In addition, Rio Tinto maintains an automatic weather station at West Angelas itself. Information in this closure plan is sourced from both stations.

## 9.1 Climate and significant weather events

The climate in the area can be characterised as arid tropical with two distinct seasons, hot wet summers and cooler dry winters. Mean daily maxima temperatures range from 40°C in summer to 22°C in winter (Figure 5).



Figure 5: Mean monthly temperatures, Newman Airport 1996-2013.

The north/north-western coastline of Australia has experienced more tropical cyclones than anywhere else on mainland Australia. Most tropical cyclones are observed during the late summer, occurring between November and May. Tropical cyclones can produce damaging wind gusts in excess of 150 km per hour, with heavy rains resulting in regional flooding. Five tropical cyclones are expected off the coast of the Pilbara each year, with two expected to make landfall. Precipitation is driven by summer cyclonic activity, with the months of August, September and October have the lowest average rainfall, and December, January and February the highest average rainfall (Figure 6). Annual rainfall is also highly variable, (Figure 7).



Figure 6: Mean monthly rainfall (1971 to 2013) at Newman Aerodrome





# 9.2 Climate and landform stability

The heavy, intense rainfall experienced in the Pilbara makes rainfall the key climatic factor that influences surface stability. Rainfall erosivity (measured in megajoule millimetre per hectare per hour per year - MJ.mm/ha/hr/yr) is the term used to describe the erosive force of rain. For Pilbara sites, long-term annual erosivity values range from ~1,000-1,600 MJ.mm/ha/hr/yr. Rainfall in the Pilbara is typically more erosive than Perth's rainfall, even though it only receives on average half the rainfall that Perth receives on an annual basis. For comparison, average annual erosivity values for Perth are ~1000 MJ.mm/ha/hr/yr from an average of 780 mm of rain a year.

Rainfall erosivity is highly variable for each rainfall event. Studies of Pilbara rainfall concluded that at Tom Price, for example, erosivity for the period 1998 to 2009 ranged from 212 – 6,349 MJ.mm/ha/hr/yr. The most erosive year recorded was 2007 at Channar, where 421 mm fell during February (704 mm fell over the whole year). This singular rain period embodied 11,994 MJ.mm/ha/hr/yr of erosive force, or 89% of the entire erosivity of rain for that year. Given the pattern of intense and infrequent rainfall events in the Pilbara, it can be expected that only a few events every year (~1-3 events) will generate the majority of runoff and erosion of that occurs each year.

The studies showed a rapid decline in erosion or sediment yield occurs when annual rain decreases below about 300 mm per year due to a corresponding decline in rainfall volumes and rainfall erosivity. However, when annual rainfall increases above ~300 mm, vegetation growth increases and becomes increasingly effective in controlling soil erosion. Hence, there is a point of maximum erosion potential at an annual rainfall value of ~200-400 mm such that surface (vegetation) cover is low due to lack of rain and ineffective for controlling erosion, yet rainfall erosivity is sufficiently high to cause erosion, as observed in the Pilbara. Outcomes from these studies have informed development of the Rio Tinto Iron Ore (WA) Landform Design Guidelines for achieving stable waste dumps.

## 9.3 Climate and vegetation growth

Water is generally the limiting factor for plant growth in the Pilbara's arid environment. As a consequence of the hot temperatures, high evaporative demand and infrequent and irregular rainfall, much of the vegetation displays xeromorphic adaptations (plant structural adaptations for survival in dry conditions). These adaptations include the ability to regulate water loss from leaves, extract water from very dry soils and match reproductive strategies with wetter periods. Many species are ephemeral and persist in soil seed banks in between wetter periods.

The adaptive capacity of Pilbara species implies a degree of resilience to changes to hydrological regimes. However, the impacts to Pilbara vegetation as a consequence of climate change are not clear. Changes in vegetation density and water use will alter the amount of runoff that occurs after a rainfall event, which in turn will alter creek flows and groundwater recharge.

Some initial studies within the wider Pilbara are underway to understand how the presence and absence of water affects vegetation growth within riparian corridors. The outcomes from these studies and other evolving research on climate change will be monitored and integrated into future closure studies to inform assumptions on climate influences and impacts.

## 9.4 Climate change

The understanding of how climate will change in the future in the Pilbara is guided by the outcomes of climate modelling, commissioned privately by Rio Tinto and other Australian government agencies. The main climate drivers for the Pilbara are the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) ocean currents. However, these ocean currents are not well represented in most global climate models, and as a result climate predictions for the northwest of Western Australia vary significantly. Consequently the impact of climate change, the change in water availability and influence on ecosystems, in the Pilbara is still unclear.

The ENSO and IOD ocean currents are currently being researched by CSIRO. At the same time, modelling is being progressively improved by various Australian Government agencies to expand our understanding of the climate drivers in the southern hemisphere, to understand the associated impacts on water availability and to predict changes to existing ecosystems.

From the modelling completed to date, our understanding of Pilbara climate change suggests the region will experience the following climate trends:

• A shift in the historical tropical cyclone season, with an earlier start and potentially later finish.

- For the period 2051 to 2099, compared to present day, tropical cyclone frequency could decrease by half, and the duration of a given tropical cyclone by 0.6 days on average. Projections also suggest that tropical cyclones could increase in size and intensity
- Continuation of the highly variable multi-decadal scale rainfall trends.
  - Projected rainfall reductions range from 1 to 24 percent for mid-century, and 9 to 24 percent for the end of the century
- A significant warming trend, influencing maximum temperatures, with the largest changes during the January to March period.
  - On average, maximum temperatures are expected to increase by 2.1 to 3.2 °C by mid-century and by a total range of 3.8 to 4.6 °C by the end of the century. For minimum temperatures the corresponding averaged increases are 1.9 to 2.4 °C (mid-century) and 4.1 to 4.6 °C (end of the century).

These changes, if realised as modelled, are likely to make successful rehabilitation in the Pilbara more challenging. Current landform designs are undertaken with inbuilt conservancy which allows for increased erosion factors, however lower average rainfall will impact ability to establish vegetative cover.

# 10. Land

# 10.1 Biogeographic overview

West Angelas lies within the Pilbara Craton, a bioregion defined by the Interim Biogeographic Regionalisation for Australia (IBRA). The Pilbara bioregion is divided into four subregions: Chichester, Fortescue Plains, Hamersley and Roebourne Plains. West Angelas is located in the Hamersley subregion which is described as a *"mountainous area of Proterozoic ranges and plateaus with low Mulga (Acacia aneura) woodland over bunch grasses on fine textured soils, and Snappy Gum (Eucalyptus leucophloia) over Triodia brizoides on the skeletal sandy soils of the ranges."* 

## 10.2 Geological setting

The deposits at West Angelas lie within Archaean rocks of the Marra Mamba Iron Formation and the West Angelas Member of the Wittenoom Formation. The Marra Mamba Iron Formation has been subdivided into three members. From oldest to youngest these are:

- Nammuldi Member: overlies the Jeerinah Formation of the Fortescue Group and is characterised by poorly bedded yellow and brown chert and cherty banded iron formation (BIF) with occasional intercalated, generally thin, fissile shale partings and rare dolomite bands;
- MacLeod Member: a sequence of BIF, banded chert and chert, interbedded with a number of thick shale bands; and
- Mount Newman Member: composed of alternating broad mesobands of iron oxides and white to yellow chert.

The West Angelas Member of the Wittenoom Formation overlies the Marra Mamba Iron Formation and consists predominantly of laminated pink, grey and khaki shales interbedded with lesser chert and minor BIF bands.

Tertiary and quaternary colluvium / alluvium (detritals) extend over much of the area, occasionally forming economic deposits when present in significant enough grades and volumes. Weathering has produced a widespread regolith profile over the iron rich bedrock. A significant hydrated zone or hardcap is present, commonly 20 - 50 m thick but reaches to +100 m in places.

Mineral waste generated at West Angelas is subsequently categorised with respect to the geological origins of the material, namely:

- detritals;
- hydrated;
- Nammuldi Member;
- MacLeod Member;

- Mt Newman Member;
- Wittenoom dolomite; and
- West Angelas shale.

#### 10.3 **Geotechnical stability of pit walls**

Rio Tinto has committed to backfilling all pit voids at West Angelas to above the groundwater recovery level to avoid the formation of pit lakes, but significant voids will still remain after closure. There is no intent to reshape or rehabilitate these in-pit areas, and the remaining pit walls will be retained in the same configuration as when mining ceases. It is recognised that there will be some degree of geotechnical instability, and that walls will have the potential to collapse in some areas.

Preliminary zones of geotechnical instability have been identified around all pits covered within the scope of this closure plan, except for Deposit G which is yet to be sufficiently defined. Methodology is based on the angle method described in DMP abandonment bund guideline<sup>3</sup>, using the conservative assumption that all pit walls are embedded into weathered rock (i.e. the polygons are lines drawn at a 25<sup>o</sup> angle from the base of the pit). Further geotechnical evaluation is being undertaken, and may result in a reduction of the current polygons. These are shown in Figure 8 – Figure 14.

The Deposit A South Dump and Deposit E South Dump intersect with the zones of instability for the adjacent pits.



Figure 8: Zone of geotechnical instability around Deposit A



Figure 9: Zone of geotechnical instability around Deposit E

<sup>&</sup>lt;sup>3</sup> Department of Industry and Resources (now DMP), Safety Bund Walls Around Abandoned Open Pit Mines, December 1997



Figure 10: Zone of geotechnical instability around Deposit B



Figure 11: Zone of geotechnical instability around Deposit A West



Figure 12: Zone of geotechnical instability around Deposit F


Figure 13: Zone of geotechnical instability around Deposit C



Figure 14: Zone of geotechnical instability around Deposit D

# 10.4 Waste characterisation and inventory

#### 10.4.1 Physical characteristics

The erodibility potential of waste types at West Angelas was assessed using a combination of site-specific geophysical test work and extrapolation from equivalent material at similar sites. Table 9 lists the waste material types by erodibility class and percentage of total mineral waste predicted to be generated by closure.

Table 9: Waste material erodibility characterisation

Waste material type	Erodibility	Percent total waste (indicative) <sup>4</sup>
Detritals	High	48%
Hydrated	Low	16%
Mt Newman Member	Low	14%
Wittenoom dolomite	High	11%
West Angelas shale	High	7%
MacLeod Member	Low	3%
Nammuldi Member	Low	<1%

<sup>&</sup>lt;sup>4</sup> The proportion of waste present in individual dumps will vary, but conglomerate data is provided for the site to show the high proportion of erodible wastes.

West Angelas mineral waste contains a significant proportion of material that is generally considered to be of high erodibility (e.g. detritals, shales), based on erodibility tests on mineral waste types undertaken by Rio Tinto across its Pilbara operations. However, there is some reason to believe that performance at West Angelas will be better than would be suggested from these erodibility tests:

- Observations made during a rainfall simulation field study at West Angelas materials in 2006<sup>5</sup> suggest lower erodibility than predicted by later laboratory tests on equivalent waste types; and
- Rehabilitated waste dump slopes at Deposit A are showing less signs of erosion that would be expected given the proportion of surface material that is classified as highly erodible.

The average bulk density of waste material is  $2.5 \text{ t/m}^3$  and loose material density of  $2.02 \text{ t/m}^3$  (Deposit A) to  $2.06 \text{ t/m}^3$  (Deposit B) with a physical swell factor (from in ground to on waste dump) of 1.25 used for volume calculations.

### 10.4.2 Geochemical characteristics

Rio Tinto has undertaken an extensive program of geochemical testing, over several years, to understand the potential for acidification and/ or metal enrichment to occur as a result of the various waste types common to mining operations in the Pilbara. The geochemical characterisation process aims to establish sulfur content, as an indicator of acid generation potential, and to undertake static (acid base accounting) and, if appropriate, kinetic testing of materials. This information is applied to the geological block model and subsequent mining model, to ensure materials with potential geochemical issues are identified prior to mining and managed, in accordance with the Rio Tinto Iron Ore (WA) Mineral Waste Management Work Practice and Spontaneous Combustion and Acid Rock Drainage (SCARD) Management Plan.

The most significant geochemical risk in Pilbara iron ore bodies is associated with sulfides, such as pyrite  $(FeS_2)$ , which can form sulfuric acid when exposed to oxygen and water. Mt McRae Shale, the geological unit most commonly associated with pyrite and acid mine drainage in the Pilbara, is not present at West Angelas. However, pyrite can also occur in Banded Iron Formations. Other sulphate minerals present at the site, such as alunite and jarosite, can also pose a geochemical risk, albeit the risk is usually lower due to self-limiting chemical processes.

Over 150 samples from the Greater West Angelas deposits (ore and waste samples) have been submitted for Acid Base Accounting (ABA) and geochemical characterisation using methodology consistent with the Global Acid Rock Drainage (GARD) Guide. For lithologies such as banded iron formation (BIF) and detrital rock types, a value of 0.3% total sulfur concentration has been adopted as the boundary value to denote potentially acid forming (PAF) material from inert/non-acid forming (NAF) material. Samples associated with elevated-sulphate (where sulfur values may range from 0.1% to greater than 1%) have been classified as PAF-LC. A sulfur cut-off of both 0.1% and 0.3% are considered for the purpose of characterisation.

To date, approximately 82% of the samples submitted for ABA were classified as non-acid forming (NAF). Approximately seven percent of the samples submitted for ABA were classified as Uncertain and were expected to be NAF. The remaining 11% of samples were classified as potentially acid forming (PAF) or PAF in a low capacity (PAF-LC).

The potentially acid forming (PAF) samples are predominately from the Newman Member of the Marra Mamba Iron Formation. These samples are banded iron formation waste samples and the majority had visible pyrite logged. The PAF-LC samples are expected to have few sulfides present with the majority of the acid produced from the precipitation of metallic ions as hydroxides between pH 4.5 and 7.

Further analysis of sulfur values was undertaken on those rock types identified with acid-forming potential (and any related metalliferous drainage). The risk posed by the high sulfur values is determined by comparing the occurrence of sulfur levels greater than 0.1% and 0.3% against the total number of recorded drill samples for all in-pit (waste and ore) samples. These results, summarised in Table 10, suggest the risk of acid drainage being generated during the operation and / or from mineral waste materials from all deposits is low.

<sup>&</sup>lt;sup>55</sup> Landloch, Field Rainfall Simulator and Overland Flow Study of Waste and Topsoil Erodibility – Nammuldi and West Angelas Mines – Pilbara Iron, December 2006

Deposit	Sulfur levels greater than 0.1%	Sulfur levels greater than 0.3 %	AMD Risk
Deposit A	2.9 %	0.3 %	Low
Deposit E	1.7 %	0.2 %	Low
Deposit B	7.0 %	0.2 %	Low
Deposit F	1.3 %	0.1 %	Low
Deposit A West	1.1 %	0.1 %	Low
Deposit C	0.9%	0.1%	Low
Deposit D	1.3%	0.3%	Low
Deposit G	0.8%	<0.1%	Low

A multi-element analysis has also been undertaken for drillhole samples across the site. Results showed that most rock types are either enriched or elevated in Fe, as correlated with the iron mineralisation associated with the ore body. Arsenic is enriched in most rock types while tin is either enriched or elevated. Other elements found to be enriched in select geological units included calcrete and dolerite from Deposit F with lead elevated, Wittenoom Formation from Deposit D with elevated levels of manganese, and waste from Deposit B, E and A West with elevated manganese, Nammuldi Waste from Deposit B with elevated manganese.

An analysis comparing the triggers against the medium concentration of select elements in each rock type indicates that:

- All rock types have average element values lower than DEC/EPA triggers for barium and phosphorus;
- The majority of rock types have elevated mean concentrations of manganese and vanadium;
- Lead levels are relatively high in Deposit E and F; and
- Zinc levels are relatively high in Deposit B.

In general, whilst concentrations of some trace elements of potential environmental concern (e.g. arsenic, lead) were enriched or elevated in some of the sampled ore and waste materials, these elements will not necessarily mobilise into groundwater. Arsenic in particular is commonly enriched in ore and waste for many Hamersley Group deposits. Iron oxy-hydroxides such as hematite and magnetite have high sorption capacities for arsenic. Groundwater contamination with arsenic is considered to be unlikely, based on historical groundwater assessments at West Angelas and experience from similar deposits in the Pilbara. Lead is similarly unlikely to mobilise into the groundwater and cause any environmental concern. These results suggest groundwater monitoring should initially include the following elements: Fe, As, Sn, Co, Cr, Cu, Mn, Ni, Pb and Zn.

### 10.4.3 Fibrous minerals

Fibrous minerals present a health hazard if fibres of a respirable size (approximately 6 microns) become airborne and are inhaled. The most common mineral associated with fibrous minerals encountered within the iron formations present at West Angelas is riebeckite. Riebeckite is usually found in fresh, unweathered BIF. The asbestiform variety of riebeckite is crocidolite or blue asbestos. The presence of riebeckite does not necessarily pose a fibrous mineral risk but it is a precursor to crocidolite, therefore, there is a higher probability of encountering crocidolite. If it is present, crocidolite seams occur primarily within the Newman Member close to, and often overlapping into the contact between the Newman Member and the underlying Macleod Member; although crocidolite can be found anywhere within the Marra Mamba Formation where iron ore mineralisation has not occurred.

Isolated occurrences of potentially hazardous fibrous material have been intersected during geological sampling and in the upper most benches of some deposits. The Rio Tinto Iron Ore (WA) Fibrous Minerals Management Plan and West Angelas Operations Fibrous Mineral Management Plan describe and provide guidelines for the management of fibrous minerals encountered during mine production, such as the encapsulation of intersected fibrous mineral waste in 2m thickness of non-fibrous mineral waste.

The small volume of potentially fibrous material that has been mined to date has been encapsulated in the Deposit A North waste dump. Similarly, fibrous material exposed in the WEPN final pit wall has since been backfilled, and poses no risk to closure. Similarly, fibrous materials excavated during the construction of the rail loop have been appropriately disposed within nominated fibrous materials burial areas.

No Potentially Hazardous or Designated Hazardous areas are demarcated in pit walls that will form the West Angelas post-mining landform and no geological units identified with a high risk of containing potentially fibrous materials are proposed to be mined in the future.

### 10.5 Local soils

Topsoil is recognised to be an important factor in achieving high quality rehabilitation results. Characterisation of soils provides an indication of soil properties and their potential impacts on vegetation establishment, growth and landform stability; although it is important to recognise that they are expected to be altered as a result of mining processes. Appropriate characterisation can also help ensure soils with adverse properties are avoided in landform design.

The dominant soil types covering the project area are shallow coherent and porous loamy soils with weak pedologic development.

In the hills and rock ridges, which represent the surface expression of the Marra Mamba Iron Formation, extensive areas without soil cover occur. Those soils that do occur are shallow and skeletal. Rocks of this Formation weather very slowly, and any soil which does form tends to be transported into the surrounding valleys and plains as a result of the sparse vegetation cover and erosion force of heavy rains derived from thunderstorms and cyclones.

The soils on slopes, although having had more time to develop than the soils of the adjacent ridges, are still influenced by the parent rock and may be shallow and stony sands or loams. These soils are generally unfavourable for plant growth due to low moisture holding capacity and poor nutrient status.

On pediments, older pediplains and alluvial plains, hard alkaline red loamy soils tend to be dominant, and may be considered as the regional mature soil type. The surface of these areas may carry a layer of small gravel, which is derived from the more resistant rocks in the area.

Typical Pilbara soil parameters are presented in Table 11.

Propert	ies	Pilbara Soils
S	Soil texture (< 2 mm soil fraction)	Sand – Clay Loam
ertie	Coarse material content (%)	0 - 93.0
Jope	Aggregate stability (Emerson Class <sup>1</sup> )	2 - 6
E D	Soil Strength (Modules of Rupture (kPa))	0 - 267
sica	Plant available water holding capacity	-
Phy	Hydraulic conductivity (Ksat(mm/h))	-
	Soil pH	5.3 – 9.5
	Salinity (dS/m)	0.007 – 0.233
es	Organic Carbon (%)	0.07 – 3.74
perti	Macro-nutrient status	-
Prop	Micro-nutrient status	-
ä	Effective Cation Exchange Capacity (meq/100 g)	1.9 – 16.8
emic	Exchangeable Sodium Percentage (%)	0.21 – 6.39
Ché	Total metal concentrations	Low

Table 11: Typical Pilbara soil parameters<sup>6</sup>

<sup>&</sup>lt;sup>6</sup> Note that the typical ranges above apply to topsoil and may not be representative of subsoil properties.

# 10.6 Soil inventory

Topsoil is often a limited resource in the Pilbara with topsoil recovery often being restricted due to the nature and terrain of the landscape. The goal of soil management is to maximise the collection of topsoil and subsoil, and to store it to maximise its viability and productivity to ensure there is sufficient soil for subsequent use in rehabilitation.

Where practical, a minimum of 200 mm of topsoil and 600 mm of subsoil is collected when new areas are disturbed. Table 12 provides the current and projected soil inventory for West Angelas, and shows that there is a total soil surplus in current stockpiles of 1.3 Mm<sup>3</sup>. However, it should be noted that a significant portion of this material is subsoil, which will be less favourable for vegetation growth than topsoil.

 Table 12: Predicted LOM soil balances for West Angelas (as of December 2016)

Material	Current volume (Mm <sup>3</sup> )	Predicted volume required for rehab (m <sup>3</sup> ) [Total volume required is 6.9 Mm <sup>3</sup> ] <sup>7</sup>
Topsoil	5.4	5.4
Subsoil	4.5	1.5 (there is a current soil surplus of 3.0 Mm <sup>3</sup> )

# 11. Water

### 11.1 Surface water

Regionally, the majority of the West Angelas deposits (Deposits A, A west, B, C, D, E, G and the F1 and F2 orebodies of Deposit F) are located within the upper reaches of the Turee Creek Catchment, which forms part of the regional Ashburton River Catchment (Figure 15). The upper catchment has a complex drainage pattern characterised by intermittent flow and infrequent wide-spread flooding, depending on the occurrence of high intensity rainfall events.

The F3 orebody of Deposit F is located in the upper reaches of the Weeli Wolli Creek catchment, part of the regional Upper Fortescue River catchment, to the west of the regional Ashburton River catchment.

The east branch of Turee Creek (Turee Creek East) represents the most significant named watercourse in the area. Immediately upstream of the confluence with Turee Creek, Turee Creek East has a catchment area of approximately 2,050 km<sup>2</sup>. This catchment has been progressively reduced by existing mining operations. The operations have reduced the Turee Creek East catchment by approximately 85 km<sup>2</sup> (4%), which is expected to be reduced by a further 2% if Deposits C, D and G are approved and implemented.

Turee Creek East flows generally westward across the West Angelas operation, continuing west southwesterly through the Karijini National Park, before merging with Turee Creek. A number of operational deposits (including Deposits A, B, E and F) and proposed deposits (including Deposits C, D and G) are intersected by tributaries of Turee Creek East. Furthermore, Deposit C intersects the flood plain of Turee Creek East itself. Several diversions are in place at various locations across the site to keep direct surface water away from operational areas, and further diversions are proposed to facilitate mining of Deposits C, D and G.

Immediately downstream of Deposits C and D, Turee Creek East flows through Karijini National Park. Surface water flows along Turee Creek East are attenuated where the creek passes between two large hills that encroach into the flow channel approximately 7 km downstream of the boundary of Karijini National Park, reducing upstream flow velocity. Over time this attenuation has resulted in the deposition of sediment upstream of the topographic feature resulting in a lowering of the channel gradient. Upstream of the feature the channel gradient is 0.0022 m/m while downstream it is 0.0045 m/m.

Additionally, surface water flows along Turee Creek East are naturally ponded behind the Mount McRae Shale which outcrops across the creek, resulting in the formation of surface water pools that may persist for an extended period following flow events. The attenuation and ponding of surface water results in increased localised groundwater recharge, which contributes to dense vegetation cover and the establishment of

<sup>&</sup>lt;sup>7</sup> Note that soil reconciliations and inventories do not yet take into account the Deposit C, D or G areas. It is anticipated that soil collected during development of these deposits will address closure inventory requirements

potentially groundwater dependant vegetation. The potential groundwater dependant ecosystem is discussed further in Section 11.2 and Section 12.4. Management of surface water diversion at closure is discussed further in Section 19.5.

### 11.2 Groundwater

The primary aquifer identified at West Angelas comprises the mineralised Mount Newman Member of the Marra Mamba Iron Formation (MMIF) and where mineralisation or weathering has occurred, the overlying Wittenoom Formation. The basal MMIF (MacLeod and Nammuldi Members) form an effective hydraulic barrier to groundwater flow. The depth to groundwater is relatively deep with groundwater flow from east to west for the majority of mining areas, with a relatively flat lying gradient. Based on a groundwater divide, possibly associated with a dolerite dyke between Deposit C2 and C3, the groundwater flow direction in the area of Deposit C3, G and B is reversed, from west to east, with a relatively flat lying gradient.

Groundwater quality at Deposit A is typically slightly alkaline to neutral with pH values ranging from 7.4 to 8.2 and salinity values ranging from 490 to 820 mg/l.

Recharge is be dominated by direct rainfall infiltration and, due to the naturally deep water table and low permeability Tertiary overburden, outside of the mine voids recharge is assumed to be very low. Ultimate recovery levels will vary depending on the level to which pits are backfilled. Recovery levels have been predicted for Deposits A, B and E under a 'zero backfill' scenario and a 'backfill to AWT' scenario (Table 13), with the difference between the two being accounted for by evaporation losses when the pit is not backfilled. Further modelling will be required to predict the intermediate scenario which minimises the amount of backfill required to reduce evaporation losses so as to prevent formation of permanent pit lakes.

Even if pits are backfilled to AWT, final water levels are expected to be lower than pre-mining levels in Deposit A, B and E. The catchment created by the mine void will serve to focus rainfall runoff and thus recharge, resulting in localised ponding at the base of the mine voids following heavy rainfall, which will dissipate via infiltration and evaporation shortly after the event. In the absence of further groundwater recovery modelling, it is conservatively assumed that pits will be backfilled to a level 2 m above the recovery level predicted in the 'backfill to AWT' scenario.

Groundwater recovery modelling has not been undertaken for Deposits C, D, F and G. In the absence of such information it would be conservatively assumed for determining an appropriate backfill level that the water table would rebound to pre-mining levels.

Deposit	Water level (mAHD) [and time taken to achieve a stable recovery level]		
	Pre-mining	Recovery assuming zero backfill	Recovery assuming backfill to AWT
Deposit A CEPN	640	574 [40 years]	610 [>100 years]
Deposit A CEPS	640	574 [65 years]	630 [30 years]
Deposit B B2 & B3	630	618 [20-30 years]	626 [20 years]
Deposit B B1	630	576 [40 years]	607 [>100 years]
Deposit E	668	586 <sup>8</sup>	650 [>100 years]

Table 13: Predicted groundwater recovery levels

Dewatering of Deposits C and D is anticipated to result in the propagation of groundwater drawdown away from the orebodies towards Karijini National Park. To address the potential impacts of dewatering on the ecohydrology of Karijini National Park, a hydrogeological conceptual model, analytical and numerical modelling have been developed based on known geology and hydrogeology.

<sup>&</sup>lt;sup>8</sup> Groundwater recovery time has not been modelled for the Deposit E zero backfill scenario.



Figure 15: Surface hydrology surrounding West Angelas

The numerical groundwater modelling suggests dewatering of Deposits C and D will result in drawdown of the groundwater of between 1m and 6m beneath the potential groundwater dependant ecosystem in Karijini National Park. The groundwater system bounded to the west by the Mount McRae Shale. As a result, the groundwater drawdown is not expected to extend more than approximately 5km beyond the boundary of Karijini National Park.

The prediction of the depth and rate of groundwater drawdown is largely dependent on the specific yield (Sy) values of the aquifer. An upper Sy value of 10% and lower Sy value of 1% were used to predict the depth and rate of groundwater drawdown. The results of the modelling adopting these specific yield values predict groundwater drawdown of 1m (lower limit, Sy 10%), 3 m (base case, Sy 3%) and up to 6m (upper limit / worst case, Sy 1%) beneath potentially groundwater dependent vegetation within Karijini National Park (Figure 16 and Figure 17).

Maximum groundwater drawdown beneath Karijini National Park (at WANG14) is not predicted to be affected by cyclonic events. However, drawdown recovery is predicted to be increased – between 0.3 m and 1 m recovery after 100 years (Figure 17 and Figure 18).

The base case scenario (Sy 3%) will result in drawdown of the groundwater of 3 m in approximately 2050. This will translate to a rate of groundwater drawdown of up to 30 cm per year. The upper limit (worst case) scenario (Sy 1%) will translate to a rate of groundwater drawdown of up to 80 cm per year.



Figure 16: Modelled groundwater drawdown for specific yield (Sy) scenarios at bore WANG14, located approximately 2.5 km within the boundary of Karijini National Park.



Figure 17: Anticipated drawdown (base case, sy=3%)



Figure 18: Effect of cyclical cyclone events on modelled groundwater drawdown at bore WANG14, located approximately 2.5 km within the boundary of Karijini National Park

Owing to the depth to groundwater, recharge within the deposits is expected to be limited. Hydrographs show no observable response in groundwater level elevation within the deposits associated with rainfall events (Figure 19). Given the limited recharge, recovery of the groundwater elevation is conservatively assumed not to occur. As such, the drawdown of the groundwater beneath potentially groundwater dependent vegetation within Karijini National Park is conservatively assumed to continue to persist beyond 100 years. However groundwater level elevations observed at bore WANG14, located approximately 2.5km within the boundary of Karijini National Park, show appreciable response up to 4m to flooding events (Figure 20).



Figure 19: Hydrographs: groundwater level elevation within the deposits in response to rainfall data



Figure 20: Hydrographs: groundwater level elevation within bore WANG14, located within Karijini National Park in response to rainfall data

The numerical groundwater modelling does not take into account ephemeral surface water flows along Turee Creek East. These flows are channelled through topographically confined gorge features (channel profile of 150 m located approximately 7 km downstream of the boundary of Karijini National Park and approximately 3 km downstream of the potentially groundwater dependent vegetation), which attenuates flows, resulting in the formation of surface water pools that may persist for an extended period following flow events (depending on climatic conditions (evaporation rates)).

Surface water flows along Turee Creek East are also naturally ponded behind the Mount McRae Shale observed outcropping at the surface on the east bank of Turee Creek East at the downstream end of the potentially groundwater dependent vegetation within Karijini National Park. Surface water flows naturally ponded behind the Mount McRae Shale may persist for an extended period following flow events (depending on climatic conditions (evaporation rates)). This potentially results in enhanced recharge of the already shallow water table.

The numerical modelling also does not accommodate additional complexity to the west of the deposits and beneath Karijini National Park due to the presence of calcrete (Figure 17, Figure 21). A significant amount of calcrete is present based on the surface geology mapping and observed intersections. Calcrete may have much higher storage capacity than the surrounding aquifer and create enhanced recharge and groundwater mounding during the wet season.

It is anticipated that the enhanced recharge due to ephemeral surface water flows along Turee Creek East attenuated through a topographically confined channel profile and ponded behind Mount McRae Shale, and the presence of saturated calcretes will compensate for the annual rate of groundwater drawdown of up to 30 cm per year (base case), or up to 80 cm per year (worst case<sup>9</sup>), potentially mitigating the effect of drawdown. Therefore, groundwater drawdown is not expected to have any significant impact on the ecohydrology of the Karijini National Park.

Groundwater drawdown is not expected to have any impact on the inherent values of the Karijini National Park. The Park is recognised for its representative ancient geologies, scenically outstanding landscape features and biological diversity (CALM 1999). Groundwater beneath Karijini National Park subject to the above discussion does not support any landscape features or biological communities of special significance in the vicinity.

<sup>&</sup>lt;sup>9</sup> Noting this worst case rate of groundwater drawdown is predicted to be of limited duration as indicated by Sy = 1% drawdown curve in Figure 16. The average rate of drawdown over the modelling period (100 years) is 3.5cm per year for Sy = 1%.



Figure 21: Hydrogeological conceptualisation, cross section; Deposit C, west of Deposit C and Karijini National Park (east-west)

# 12. Biodiversity

# 12.1 Terrestrial habitat

Eight broad habitat types were mapped at West Angelas prior to mining (Table 14), all of which are expected to be represented in undisturbed areas after closure.

Plain, hilltop and Acacia woodland are the dominant habitat types in the area.

Hilltop, gully, cracking clay and creek habitats are of high value due to the diversity of microhabitats and potential to support conservation significant fauna species. Mesa top, mulga woodland and acacia woodland habitat is considered to have moderate habitat value due to the specialty habitat or number of fauna that may utilise the area, while plains habitat has lower value. In contrast, cleared habitat, created through mine disturbance, provides little food, shelter, water or any other life essential and is considered to have little to no habitat value.

Re-introduction of fauna is not considered as part of this closure plan. Instead, natural migration of fauna species into rehabilitated land is encouraged by creating habitats with similar composition to pre-mining communities in appropriate locations and with consideration of the post-closure soil and landforms design.

Table 14: Description of pre-mining habitats identified at West Angelas

Туре	Basic description
Hilltop	Hills, ridges, plateaux remnants, gorges and breakaways of varied geological origin. Soil is generally skeletal sandy clay loams with greater than 80% stony detrital material.
	Under natural conditions this habitat zone is characterised by a scattered overstorey of Snappy gum <i>Eucalyptus leucophloia</i> and mulga (Acacia aneura complex) isolated trees over sparse shrubland of a combination or selection of <i>Senna artemisioides</i> subsp. <i>artemisioides</i> , <i>S. artemisioides subsp. filifolia, Ptilotus rotundifolius, Tribulus suberosus,</i> <i>Eremophila fraseri</i> and <i>Acacia ancistrocarpa</i> sparse shrubland to isolated shrubs over <i>Triodia pungens</i> hummock grassland.
	Rocky, sheltered ridges and breakaways provide a suite of specialist plants or species more typical of lowlands.
	This habitat creates a diverse array of microhabitats and refugia. The habitat often contains rock shelters in the form of overhangs, cracks, crevices, caves and areas for water to pool during the wet season. Vegetation provides microhabitats in the form of logs, debris and hollows.
	This habitat zone will be present in undisturbed areas of the mine and may evolve around the edge of the disturbed mine area especially where the pit shell intersects local hills after erosion processes occur. However the characteristics of this habitat are not compatible with the closure landform is unlikely to be restored or introduced as part of the rehabilitation activities.
Mesa top	Mesa top habitat is distinguished by its elevated plateau topography. This habitat is characterised by <i>Eucalyptus leucophloia</i> , <i>E. gamophylla</i> , <i>Acacia pruinocarpa</i> and mulga ( <i>A. aneura</i> complex) open woodland to sparse trees, over <i>A. maitlandii</i> , <i>A. hamersleyensis</i> , <i>Keraudrenia velutina</i> and <i>Senna glutinosa</i> subsp. <i>glutinosa</i> open shrubland, over <i>Triodia pungens</i> , <i>T. longifolia</i> and/or <i>T. wiseana</i> open hummock grassland.
	This habitat is characterised by a low diversity due to the elevation and therefore the isolation from accessible surrounding habitats. However, invertebrate fauna can be quite diverse and specialised as a result of this isolation.
	This habitat zone will not be substantially disturbed by mining activities and will be present in undisturbed areas to the east of Deposit B. The characteristics of this habitat are not compatible with the closure landform is unlikely to be restored or rehabilitated as part of the rehabilitation activities.

Туре	Basic description
Major gorge	Very steep topography with an irregular surface with little exposed soil. The soil, when available, is sandy to sandy-clay.
	This habitat commonly includes <i>Acacia aptaneura</i> open woodland over <i>Ptilotus obovatus</i> isolated shrubs over <i>Themeda triandra</i> and <i>Eriachne</i> sp. open tussock grassland and <i>Triodia pungens</i> isolated hummock grasses. <i>Astrotricha hamptonii, Ficus brachypoda</i> and <i>Cyperus cunninghamii</i> are species found only in the major gorge are considered descriptive of this habitat type, although not dominant.
	This habitat creates a diverse array of microhabitats and refugia. The habitat often contains rock shelters in the form of overhangs, cracks, crevices, caves and areas for water to pool during the wet season. Vegetation provides microhabitats in the form of logs, debris and hollows.
	This habitat zone will be present in undisturbed areas of the mine. The characteristics of this habitat are not compatible with the closure landform is unlikely to be restored or rehabilitated as part of the rehabilitation activities.
Plains	Low and occasionally slightly undulating alluvial plains including outwash areas and broad drainage basins. Under natural conditions soils often consisting of sandy-clay soils covered by rocky lag gravel.
	The habitat is characterised by <i>Eucalyptus leucophloia, E. gamophylla, Corymbia hamersleyana, Acacia pruinocarpa, A. inaequilatera</i> and species in the <i>A. aneura</i> complex open woodland to sparse trees over <i>Acacia</i> spp., <i>Eremophila</i> spp., <i>Ptilotus</i> spp., <i>Senna</i> spp. and <i>Solanum lasiophyllum</i> open shrubland over <i>Triodia</i> spp. open hummock grassland.
	The habitat includes minor drainage lines, where <i>Triodia longifolia</i> , Gossypium robinsonii and <i>Acacia ancistrocarpa</i> are characteristic.
	This habitat type contains limited microhabitats with the dominant <i>Acacia</i> species providing no tree hollows, few logs, limited leaf litter and sparse vegetation. SRE invertebrate species usually comprise mygalomorph (trapdoor) spiders, scorpions, pseudoscorpions and isopods. Most SRE invertebrates prefer the southern footslopes where sun exposure is reduced and the level of moisture under shrubs and trees is increased.
	This habitat zone will be present in undisturbed areas of the lease. Characteristics of this habitat may be suitable for rehabilitation planning and could be considered where there is the opportunity for deep soils to develop, i.e. on waste dumps.
<i>Acacia</i> woodland	Flat with no or very small drainage channels, under natural conditions soils often consist of a clay loam with continuous layers of small ironstone pebbles on the surface.
	The habitat is characterised by open to medium dense woodland with a tree stratum of mulga ( <i>Acacia aneura</i> complex) and scattered <i>Acacia pruinocarpa</i> , over <i>Acacia maitlandii</i> and <i>Ptilotus</i> sp. sparse shrubland, over <i>Triodia wiseana</i> and <i>T. pungens</i> open hummock grassland dominated the mixed <i>Acacia</i> woodland habitat.
	Similar to the plains habitat, this habitat type contains limited microhabitats with the dominant <i>Acacia</i> species providing no tree hollows, few logs, limited leaf litter and sparse vegetation. However, avifauna is most diverse after significant rainfall, and when acacia shrubs and trees are flowering.
	This habitat zone will be present in undisturbed areas of the lease. Characteristics of this habitat may be suitable for rehabilitation planning and could be considered on flat areas that sustained mixed acacia woodland vegetation prior to disturbance.

Туре	Basic description
Mulga woodland	Flat areas dominated by overland surface water flows, rather than concentrated flow along drainage lines, following very heavy rainfall. Soils are typically comprised of sandy-clay with no rocks.
	This habitat consists of both groved and banded mulga, where different species of the <i>Acacia aneura</i> complex were present in a closed woodland, over <i>Ptilotus obovatus</i> and juvenile mulga trees sparse shrubland, over <i>Maireana</i> sp. and <i>Salsola australis</i> isolated herbs and <i>Aristida</i> sp. and <i>Cymbopogon obtectus</i> isolated tussock grasses creating distinct micro-habitats that include dense leaf litter and shaded zones.
	Similar to the <i>Acacia</i> woodlands habitat, this habitat type contains limited microhabitats with the dominant <i>Acacia</i> species providing no tree hollows, few logs, limited leaf litter and sparse vegetation. Avifauna is most diverse after significant rainfall, and when acacia shrubs and trees are flowering.
	This habitat zone will be present in undisturbed areas of the lease. Characteristics of this habitat may be suitable for rehabilitation planning and could be considered on flat areas that sustained mulga woodland vegetation prior to disturbance.
Cracking clay	Characterised by sand-clay to clay soils with an undulating surface caused by crabholes and gilgai. Rocks and pebbles were very rare and when present, the rock type was consistently ironstone.
	I his habitat supports very few trees or tall shrubs and is characterised by open and sparse low vegetation with approximately half of its area being bare ground. Isolated shrubs of Salsola australis, Boerhavia paludosa and Ptilotus nobilis subsp. nobilis were present over open tussock grassland of Aristida sp., Brachyachne sp. and Astrebla pectinata.
	across the Pilbara, and contains species which are both rare and edaphically restricted (i.e. distribution is influenced by the soil rather than by the climate).
	This habitat zone will be protected as far as practicable during mining activities and will be present in undisturbed areas to the north of Deposit A West and south of Deposit B. The soil profile required to restore this habitat is not compatible with the closure landform; although, following further investigation, opportunities may exist to establish a community in an appropriate locations by relocating habitat scheduled to be destroyed (e.g. areas under Deposit B waste dumps).
Creek	A linear habitat characterised by regular surface water flows, defined banks and associated riparian vegetation corridor. The creek habitat includes areas that are periodically flooded due to high surface water flow volumes (floodplains).
	Vegetation is characterised by open woodland of <i>Eucalyptus victrix, Acacia citrinoviridis</i> and <i>Acacia aptaneura</i> , over Senna artemisioides subsp. oligophylla, Rhagodia eremaea, <i>Ptilotus obovatus, Tephrosia rosea</i> and <i>Malvaceae</i> spp. shrubland over <i>Themeda triandra</i> and <i>Bothriochloa</i> sp. sparse tussock grasses and/or <i>Triodia pungens</i> sparse hummock grasses.
	Creek habitats act as wildlife corridors that help flora and fauna disperse across the landscape. There is a high diversity of microhabitats including logs, debris, tree hollows and soft soils, as well as temporary and permanent pools.
	This habitat zone will be present in undisturbed areas outside of the mine. Disturbed creek habitat, i.e. access roads that cross creeks and discharge related infrastructure, will be rehabilitated with the aim of returning the land to functional creek habitat.

# 12.2 **Conservation significant flora and communities**

Table 15 describes the Priority flora that have been identified at or near the West Angelas operations and have biodiversity value because of their rare and/or threatened status. No species of flora currently listed as Threatened have been identified at or near the West Angelas operations.

Table 15:	Conservation significant flora identified near of	or at West Angelas.
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Flora taxon	Conservation status WA	Habitat comments
<i>Eragrostis</i> sp. Mt Robinson (S. van Leeuwen 4109)	1	Red brown skeletal soils, ironstone. Steep slopes, summits
<i>Eremophila</i> sp. Hamersley Range (K. Walker KW 136) PN	1	Summit of hill, high in landscape, steep rock slopes and scree, skeletal brown-red soil over massive banded ironstone of the Brockman Iron Formation
<i>Eremophila</i> sp. West Angelas (S. van Leeuwen 4068)	1	High in landscape, summit of hill, gently undulating to steep terrain, skeletal red gritty soil over massive banded iron of the Brockman Iron Formation
<i>Josephinia</i> sp. Marandoo (M.E. Trudgen 1554)	1	Outer edge of creek vegetation. Soil: Orange-brown (terracotta) coloured clay-loam
Rhodanthe ascendens	1	Clay
Tetratheca fordiana	1	Shale pocket amongst ironstone
<i>Vittadinia</i> sp. Coondewanna Flats (S. van Leeuwen 4684)	1	Flat plain. Red sandy clay loam.
Aristida lazaridis	2	Sand or loam
Eremophila pusilliflora	2	Flat terrain, low in landscape, base of broad valley, stony gibber plain above shallow drainage line, red clay loam
Euphorbia clementii	2	Sandplains, gravelly hillsides, stony grounds
<i>Hibiscus</i> sp. Gurinbiddy Range (M.E. Trudgen MET 15708) PN	2	Near summit of hill, high in landscape, skeletal red brown stony soil over massive ironstone of the Brockman Iron Formation
<i>Oxalis</i> sp. Pilbara (M.E. Trudgen 12725)	2	Gully. Brown red loam, cobbles and pebbles
Teucrium pilbaranum	2	Crab hole plain in a river flood plain, margin of calcrete table
Acacia effusa	3	Stony red loam. Scree slopes of low ranges
Acacia aff. subtiliformis	3	Rocky calcrete plateaux
Dampiera metallorum	3	Rocky ledges and breakaways with loose scree material in lower section of plot.
<i>Goodenia</i> sp. East Pilbara (A.A. Mitchell PRP 727)	3	Red brown clay soil, calcrete pebbles. Low undulating plain, swampy plains
Grevillea saxicola	3	Breakaways and scree slopes, orange-brown loam soils
Indigofera gilesii	3	Pebbly loam amongst boulders and outcrops. Hills.
<i>Oldenlandia</i> sp. Hamersley Station (A.A. Mitchell PRP 1479)	3	Cracking clay, basalt. Gently undulating plain with large surface rocks, flat crabholed plain
Olearia mucronata	3	Schistose hills, along drainage channels
Pilbara trudgenii	3	Skeletal, red stony soil over ironstone. Hill summits, steep slopes, screes, cliff faces

Flora taxon	Conservation status WA	Habitat comments
<i>Rhagodia</i> sp. Hamersley (M. Trudgen 17794)	3	Broad plain at the base of hills (enclosed on all sides). Red brown clay/loam. Ironstone pebbles
Rostellularia adscendens var. latifolia	3	Ironstone soils. Near creeks, rocky hills
<i>Sida</i> sp. Barlee Range (S. van Leeuwen 1642)	3	Skeletal red soil pockets. Steep slopes
<i>Themeda</i> sp. Hamersley Station (M.E. Trudgen 11431)	3	Red clay. Clay pan, grass plain
<i>Triodia</i> sp. Mt Ella (M.E. Trudgen 12739)	3	Light orange brown, pebbly loam. Amongst rocks and outcrops, gully slopes
Acacia bromilowiana	4	High in landscape, summit of hill and on steep slope, skeletal red gritty soil over massive basalt type rock
Goodenia nuda	4	Wide alluvial plain or creek beds. Red brown clay loam, ironstone.
Lepidium catapycnon	4	Skeletal hills, hillsides

### 12.3 Priority and/or Threatened Ecological Communities

There are no Threatened Ecological Communities in the West Angelas region. However, the West Angelas Cracking Clay Priority Ecological Community (PEC) (Figure 22) is listed in Western Australia as a Priority 1 community. It's considered significant because it is relatively uncommon in the Pilbara and because it is in very good condition, attributed to the absence of historic cattle grazing in the region. Notwithstanding this, cracking clay communities at West Angelas (and other areas in the Pilbara) appear to be predominantly sustained by surface water (sheet) flows generated by incident rainfall, and its condition in recent years has been described as poor following a number of years of below average rainfall.

The PEC is described as open tussock grasslands of *Astrebla pectinata, A. elymoides, Aristida latifolia,* in combination with *Astrebla squarrosa* and low scattered shrubs of *Sida fibulifera,* on basalt derived cracking clay loam depressions and flow lines.

The PEC footprint is treated as an exclusion zone and direct disturbance is avoided during mine construction and operations, although approximately 15.5 ha is proposed for clearing to facilitate mining of Deposit D.

Preliminary studies have been undertaken to further understand cracking clay community soil profiles, with potential translocation in mind or required. Studies of the soil profile<sup>10</sup> have shown that there are two clay layers: an upper vertosol cracking clay which overlays a red kandasol structureless clay. Vegetation roots do not appear to be capable of penetrating the kandasol clay layer. Based on the chemical and physical analysis of the vertosol, there are indications that short-term stockpiling of the material should not affect its viability.

A translocation trial is currently not being perused further due stakeholder feedback however if approved materials from the PEC located at Deposit D will be segregated stockpiled in the advent that a translocation trial should become favourable.

<sup>&</sup>lt;sup>10</sup> Astron, West Angelas Cracking Clay Study, February 2015



Figure 22: West Angelas Cracking Clay Community Locations

### 12.4 Potential groundwater dependant ecosystem of Karijini National Park

Biological surveys conducted in the West Angelas region have a identified a potentially groundwater dependent ecosystem located inside the Karijini National Park boundary. The potential groundwater dependent ecosystem (Figure 23 and Figure 24) is defined by stands *Eucalyptus victrix* and *Eucalyptus camaldulensis* at elevated densities. An evaluation of biological survey data suggests that approximately 22 ha of such vegetation may be at 'low to medium' risk of impact and 4.2 ha of 'medium' risk of impact as a result of this magnitude of groundwater drawdown.

As discussed in Section 11.2 groundwater drawdown has been estimated to occur within the Park boundary between 1 and 6 meters beneath the potential groundwater dependant ecosystem, at a rate of up to 80 cm per year as a worst case scenario. However, it is expected that potentially groundwater dependent species will be able to maintain a functional connection with groundwater via surface water recharge mechanisms stated in Sections 11.1 and 11.2. As such groundwater drawdown is not expected to have any significant impact on the eco-hydrology of the Karijini National Park nor impact to the inherent values of the Park.

### 12.5 Seed provenance and selection

Locally collected seed is needed to assist in revegetation and the creation of a self-sustaining ecosystem. Over time the viability of seeds in stockpiled topsoil decreases, and thus the quality of the topsoil deteriorates. In addition the topsoil that was salvaged prior to disturbance may not contain seeds of all the target species of its new location / habitat.

Seed mixes for rehabilitation are of local provenance. Specific seed mixes are selected to provide a range of species appropriate to the desired habitat, taking into consideration landscape position and slope. In areas where erosion risks are identified, seed mixes may be modified to include or increase the portion of species that provide rapid cover.

Rio Tinto Iron Ore purchases seeds from commercial seed suppliers, with emphasis on ensuring that there are appropriate local provenance seeds available for rehabilitation of each of its sites. Seeds are stored in purpose-built, climate controlled storage facilities to maximise long term viability.

The inclusion of rare and threatened species in rehabilitation programmes is limited by:

- habitat preference (preference for drainage lines, gullies, calcretes or other habitat not suitable or similar to those likely to be present in the rehabilitation landscapes);
- abundance very few populations or small populations from which to source seed;
- difficult taxonomy / unresolved taxonomy issues and thus status of species highly uncertain;
- growth form e.g. short lived annual species with preference for growth under woodland canopies;
- availability of seed at the time when rehabilitation occurs; and/or
- seed dormancy.

Given these issues, the main focus of rehabilitation programs is to restore vegetation complexes that include the more common species present in the particular habitat type, and to achieve a diverse range of strata. Seed mixes may include species of conservation significance if they are available, but presence of these species in rehabilitation areas is more likely to result from natural recruitment from surrounding areas.



Figure 23: Potential groundwater dependant ecosystem risk mapping



Figure 24: Potential groundwater dependant ecosystem risk mapping insert reference Map 2

### 12.6 Invasive flora

Flora and vegetation surveys have recorded eight species (Table 16) on the Department of Parks and Wildlife Impacts and Invasiveness Ratings list for the Pilbara.

Scientific Name	Common Name	Ecological Impact	Invasiveness
*Acetosa vesicaria	Ruby Dock	High	Rapid
*Cenchrus setiger	Birdwood Grass	High	Rapid
*Cenchrus ciliaris	Buffel grass	High	Rapid
*Malvastrum americanum	Spiked Malvastrum	High	Rapid
*Sigesbeckia orientalis	Indian Weed	Unknown	Rapid
*Sonchus oleraceus	Common Sowthistle	Low	Rapid
*Setaria verticillata	Whorled Pigeon grass	High	Rapid
*Bidens bipinnata	Beggars Tick	Unknown	Rapid

Table 16: Weed species recorded at West Angelas

# 12.7 **Conservation significant fauna**

Conservation significant species have been identified as present at or near the site and/or may be present at the site due to the presence of appropriate habitat within their known range, are listed in Table 17.

Table '	17.	Snecies	of conservat	ion significa	nce and as	sociated ha	hitats at I	Nest An	nelas
rabie	17.	Species	UI CUISEIVal	างกา ธารุกแกษส	ince and as	socialeu na	iniais ai i	VESI AII	yeias

Fauna species	Conservation status WA	EPBC Act status	Habitat occurrence
Dasyurus hallucatus (Northern quoll)	Schedule 2	Endangered	Gullies Disturbed
<i>Rhinonicteris aurantia</i> (Pilbara leaf-nosed bat)	Schedule 3	Vulnerable	Gullies Hilltop
Liasis olivaceus barroni (Olive python)	Schedule 3	Vulnerable	All hill habitats
Falco hypoleucos (Grey falcon)	Schedule 3	Vulnerable	Acacia woodland Mulga woodland All drainage habitats
Macroderma gigas (Ghost bat)	Schedule 3	Vulnerable	Gullies Hilltop
Apus pacificus (Fork-tailed swift)	Schedule 5	Migratory	All drainage habitats
Merops ornatus (Rainbow bee-eater)	Schedule 7	Migratory	All valley habitats
Falco peregrinus (Peregrine falcon)	Schedule 7	-	All habitats
Ramphotyphlops ganei	Priority 1	-	All habitats
<i>Underwoodisaurus seorsus</i> (Pilbara barking gecko)	Priority 2	-	All hill habitats
Pseudomys chapmani (Western pebble- mound mouse)	Priority 4	-	All hill habitats
Leggadina lakedownensis (Short-tailed mouse)	Priority 4	-	All

# 13. Progressive rehabilitation

Regular reviews of the mine plan are used to identify disturbed areas of the site where mining activity has been completed. These areas are then reviewed for potential to undertake progressive rehabilitation works. Lessons learnt during these activities and from subsequent monitoring campaigns are used to inform and update our standard management practices and provide input into suitability of final closure criteria for the site.

# 13.1 Borrow pits and rail loops

Rehabilitation at most of the West Angelas borrow pits and rail loop sites was undertaken between 2000 and 2003. Established monitoring transects include:

- Five borrow pits at the highway end of access road (Highway 1-5);
- Four rail loop rehabilitation areas (Rail Loop 1a, 1b, 2 and 3);
- Three borrow pits adjacent to the airstrip (Airstrip 1-3); and
- Three reference transects C7, C8 and C9.

The vegetation is well established (Figure 25), and in most cases sites compare favourably with one or more of the reference sites. Over half the species present in the rehabilitation sites were recorded in three reference sites. They include a range of perennial shrub and grass species. The absence of some species from rehabilitation may reflect pre-mining site differences as well as rehabilitation establishment and survival.

Other species were present in rehabilitation but not in reference sites. Likely reasons are the greater sampling effort in rehabilitation (i.e. more sites) and the increased presence of early colonizing species. The number of species in the rehabilitated sites is expected to increase with time through natural re-colonisation from surrounding areas.

All sites appear stable; and some sites may be nearing a stage where signoff could be considered.



Figure 25: Rehabilitation progress at Highway 3.

#### 13.1.1 Waste dumps

Two waste dumps areas at Deposit A South waste dump and North (also known as East) waste dump were rehabilitated in 2012. The South waste dump (Figure 26) area is a 6 ha portion of the lower lift, and North waste dump (Figure 27) area is a 1.5 ha section of the lower lift. Reference sites have been established in unmined areas that consist of similar vegetation, soil and terrain characteristics of the area to be rehabilitated.

Monitoring undertaken in 2015 indicates that both rehabilitation areas are performing very well, with values for all parameters (e.g. plant density, plant cover, species richness, diversity, weed count) similar to, or in many cases better than those in reference sites. Spinifex density was within the range recorded in reference sites, but numbers were lower than had been recorded in 2014. This is not unexpected, and probably reflects the loss of some seedlings due to environmental factors.

Both rehabilitation areas are also performing well with respect to erosion. The North Dump has few gullies, and those that are present appear to be stable. There are two obvious gullies on the South Dump, although one of these appears to be stable. There is one significant gully on a corner of the dump which appears to be increasing. Monitoring will continue, and corrective works undertaken if it appears to threaten dump stability.

The generally good performance with respect to erosion is of particular significance because the final rehabilitation design specifications are less conservative than would applied based on the large proportion of detritals and shales which are currently classified as being highly erodible based on recent laboratory test work. However, this performance is consistent with the results of 2006 field simulations of the material, and further work is proposed to confirm an appropriate design specification. It should be noted that less conservative design specifications (e.g. higher lifts, higher slope angles) are advantageous with respect to reducing the overall footprint and/or reducing the number of berms on the rehabilitated surface, and would accordingly be adopted where appropriate.



Figure 26: Rehabilitation progress at Deposit A South waste dump (2015) 3 years after seeding.



Figure 27: Rehabilitation progress at Deposit A North (East) waste dump (2015) 3 years after seeding.

# 14. Contaminated sites

Rio Tinto Iron Ore maintains registers for potentially contaminating activities and known and suspected contaminated sites which have been formally reported under s11 of the *Contaminated Sites Act 2003* (WA). The registers are informed by regular preliminary site investigations to identify such activities and sites. Currently no locations at West Angelas have been reported under the *Contaminated Sites Act 2003* (WA). Potentially contaminating activities and land uses as described in the guideline 'Assessment and management of contaminated sites' (DER, 2014), are however performed onsite and include amongst others things:

- Airport facilities;
- Automotive repair workshops (light and heavy machinery);
- Substations and transformers;
- Explosives storage;
- Putrescible landfill sites;
- Mineral processing, mining, screening and crushing facilities;
- Rail transport corridors;
- Hydrocarbon storage, handling and dispensing facilities;
- Sewage waste water treatment plants and irrigation areas; and
- Disturbance of potentially acid forming materials during the course of mining.

A contaminated sites assessment will be undertaken prior to closure as part of the decommissioning process. Specific plans will be developed to remediate or manage contamination, where required, to support the final land use.

# 15. Cultural heritage

Rio Tinto Iron Ore recognises and respects the significance of Australia's cultural heritage, and in particular the cultural heritage of Aboriginal people who have traditional ownership of, and/or cultural connections to, the land on which we operate. Extensive archaeological and ethnographic surveys have been undertaken in the West Angelas area, and these surveys help to inform the heritage values of the area. We take all reasonable and practicable measures to prevent harm to cultural heritage sites, this includes during works associated with rehabilitation and closure. Where this is not possible, steps are taken to minimise or mitigate impacts and ensure required statutory approvals are obtained. Closure works consider issues such as post closure access requirements to culturally significant sites and appropriate return of any materials salvaged during mining operations.

# 15.1 Relevant Aboriginal groups

The Yinhawangka and Ngarlawangga Peoples are the traditional custodians of the land identified within this closure plan.

Yinhawangka is represented by Yinhawangka Aboriginal Corporation (YAC) and Ngarlawangga is represented by Ngarlawangga Aboriginal Corporation assisted by Ngurra Barna Aboriginal Corporate Services. Yamatji Marlpa Aboriginal Corporation (YMAC) currently act as Ngarlawangga's heritage body. Members of these corporations are geographically dispersed with key locations being Wakathuni and Bellary near Tom Price, Onslow, Roebourne, Karratha and Port Hedland.

Consultation with regards to closure has been limited to date. Topics that require consultation include the on-going access to heritage sites post closure and the ultimate resting place of any artefacts salvaged.

# 15.2 Ethnographic and archaeological values

In line with statutory requirements and internal heritage management standards, archaeological and ethnographic surveys have identified a rich and diverse region of material culture that includes an abundance of artefact scatters, rockshelters, scarred trees and rock art, in part due to the proximity to Turee Creek East and its tributaries and the presence of readily accessible naturally formed shelters. The large concentration and close proximity of artefact scatters and scarred trees to rockshelters seemingly demonstrates the adaptation to the local environment and the story of subsistence of people moving through this part of the country.

Several sites of high archaeological and/or ethnographic significance to the Yinhawangka People have been identified in the region and works have been modified to mitigate direct impacts to these sites outlined in Management Plans drafted in consultation with the Yinhawangka.

Whilst this closure plan does not include strategies for maintaining or restoring cultural values, it does recognise that post-closure access to some of these sites may be required and that the area will need to be made safe for this purpose.

# 16. Regional Community

The area surrounding the mine is unallocated crown land with no homesteads or Aboriginal communities in close proximity. The nearest town, Newman, is located approximately 120 km south-east of West Angelas.

West Angelas operates solely as a Fly-In Fly-Out (FIFO) operation. The majority of the workforce flies in and out of the privately owned airstrip adjacent to the mine village. As a result, there is little direct social interaction between the workforce and any surrounding local communities.

# 17. Workforce

West Angelas is operated wholly as FIFO operations, with no personnel residing in the Pilbara. The majority of staff is flown directly from Perth to the site operated airport, with small numbers also flying directly from Busselton and Broome. Personnel are housed on site, in a fully serviced accommodation facility that will be decommissioned as part of this closure plan.

Mining activities are anticipated to continue at a similar rate within the wider region after the West Angelas mine ceases to operate. Thus employment opportunities and mine related services are not anticipated to be significantly impacted by closure of the mine.

# **IDENTIFICATION AND MANAGEMENT OF CLOSURE ISSUES**

# 18. Risk evaluation process

A closure risk assessment was completed to identify and assess closure issues for West Angelas. The risk assessment is included in Appendix D. The assessment was completed by an internal panel of multidisciplinary subject matter experts with the aim of:

- identifying hazards, aspects and opportunities that could influence the successful closure of the site;
- evaluating the resulting risks to people, property and the environment; and
- defining the actions required to reduce the risk to below the risk acceptance threshold.

Risk was evaluated on the basis of the maximum reasonable outcome consequence and the likelihood of that consequence occurring. Risks were evaluated inclusive of current management and commitments, and represent current residual risk.

Issues are assessed against the following consequence criteria:

- Health: reversible health effects of little concern (very low) to multiple fatalities (very high);
- Personal safety: inconvenient first aid treatments (very low) to multiple fatalities (very high);
- **Environment**: reversible impact (very low) to widespread, long-term impacts (very high). As some environmental impacts can escalate if immediate identification and remediation is not possible, environmental consequences are also evaluated by:
  - **On-site**: referring to impacts that occur during the pre-closure and decommissioning phases, when staff are able to utilise site equipment and quickly react to remediate impacts; and
  - **Off-site**: referring to impacts that occur during the post-closure phase, when remediation may not immediately follow impact identification, due to a need to bring equipment and experts back to site to remediate.
- **Community trust**: mistrust amongst a small section of the wider community (very low) to widespread mistrust with key stakeholders (very high); and
- **Compliance**: non-conformance to internal requirements (very low) to prosecution for breach of regulatory licence(s) (very high).

Risks are classified as follows:

- Low (Class I): Risks that are below the risk acceptance threshold and do not require further management;
- **Moderate** (Class II): Risks that lie on the risk acceptance threshold and require regular review to ensure management remains adequate and fit-for-purpose;
- **High** (Class III): Risks that, based on the current level of knowledge, could exceed the risk acceptance threshold and require proactive management and / or resolution of knowledge gaps; and
- **Critical** (Class IV): Risks that, based on the current level of knowledge, will exceed the risk acceptance threshold and need urgent and immediate attention to develop an alternative approach.

Actions are assigned to risks that exceeded the risk acceptance threshold and therefore require additional control measures to reduce the risk to an acceptable level. Actions are also assigned to address knowledge gaps where it is assessed that further information is required to better understand and/or adequately assess the risk presented by an issue. This would typically be the case in the early stages of closure where the detailed knowledge of the issues may be low.

# 19. Management of key issues

The DMP/EPA *Guidelines for Preparing Mine Closure Plans* lists a number of rehabilitation and closure issues that may be relevant for mine sites, including five that are identified as key issues. An evaluation of the relevance of each of these issues to West Angelas mine is presented in Table 18. The information in this table is intended to compliment that contained in the risk assessment presented as Attachment D.

Table 18: Releva	ance of potential closure	e and rehabilitation issue	s to West Angelas
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Issue	Evaluation of relevance to West Angelas	Further discussion	
Acid and metalliferous drainage	Geochemical studies have identified a low AMD risk for West Angelas.	Not addressed further in this chapter	
Challenges associated with rehabilitation and revegetation	Rehabilitation conducted to date, which includes trial rehabilitation areas on two waste dumps, appears to have resulted in good outcomes.	Not addressed further in this chapter	
Dispersive, sodic and erosive materials	West Angelas mineral waste contains a high fraction of material that is classified as highly erodible	Section 19.1	
Radioactivity	Not a significant issue for this site	Not addressed further in this chapter	
Mine pit lakes	The current closure strategy involves backfill to a level that prevents the formation of pit lakes	Not addressed further in this chapter	
Geotechnical instability	Several waste dumps intersect zones of instability around pit walls	Section 19.2	
Inadvertent public access	Abandonment bunds will be required to restrict inadvertent public access	Section 19.3	
Hazardous materials	Hazardous materials (e.g. hydrocarbons, ammonium nitrate) will be removed prior to, or during, decommissioning	Not addressed further in this chapter	
Hazardous and unsafe facilities	All infrastructure will either be demolished during decommissioning, or handed to the State in accordance with State Agreement requirements	Not addressed further in this chapter	
Contaminated sites	There are no reportable contaminated sites	Not addressed further in this chapter	
Fibrous materials	Fibrous mineral wastes are present	Section 19.4	
Non-target metals and target metal residues in mine wastes	No chemical processing occurs at the site	Not addressed further in this chapter	
Adverse impacts on surface and groundwater quality	There is not predicted to be any significant surface or groundwater impacts	Not addressed further in this chapter	
Design and management of surface water structures	Surface water diversions are present	Section 19.5	
Dust emissions	This is not considered to be a significant closure issue for the site due to its remote location	Not addressed further in this chapter	
Flora and fauna diversity/threatened species	Cracking clay Priority Ecological Communities are located in close proximity to the mining footprint. Current groundwater modelling and environmental impact assessment indicate changes in groundwater regime at a potential groundwater dependant ecosystem within Karijini National Park.	Section 19.6 Section 19.7	
Visual amenity	This is not considered to be a significant closure issue for the site due to its remote location	Not addressed further in this chapter	

Issue	Evaluation of relevance to West Angelas	Further discussion
Heritage issues	Management of cultural heritage values is conducted through processes established under the Indigenous Land Use Agreement, and strategies incorporated into Cultural Heritage Management Plans.	Not addressed further in this chapter
Alteration of the direction of groundwater flow	Alteration of groundwater flows is not expected to be significant	Not addressed further in this chapter
Alteration of the depth to water table of the local aquifer	Groundwater is not expected to recover to pre-mining levels, and there will be a long-term groundwater drawdown footprint.	Section 19.7
Alteration of the hydrology and flow of surface waters	Alterations to the hydrology and flow of surface waters are expected to be localised and not significant.	Not addressed further in this chapter

### 19.1 Management of erodible mineral waste

#### 19.1.1 Principles of waste dump design

Waste dumps located on mine sites that are operated by Rio Tinto are designed and rehabilitated in accordance with internal Landform Design Guidelines<sup>11</sup>. This document provides guidance on:

- the objectives of waste dump design, which is to achieve dumps that are:
  - o safe;
  - o stable;
  - o aesthetically compatible with the surrounding landscape;
  - o vegetated;
  - o non-polluting;
  - o compatible with the agreed post-mining land use; and
  - o progressively rehabilitated;
- selection of appropriate locations for the siting of waste dumps;
- appropriate shapes and designs of waste dumps;
- appropriate surface treatments; and
- links to other relevant internal and external guidance material.

These Guidelines are updated on a regular basis to incorporate learnings from research, studies and rehabilitation implementation projects. The most significant recent update occurred in 2012 to provide designs for waste dumps based on the specific waste types present. This was the result of several years of materials testing and landform evolution modelling studies of wastes typically found in the Pilbara including those at West Angelas, with design recommendations based on the assumption that an average erosion rate of 5/ha/year (with a maximum of 10/ha/year) will be acceptable. Further studies have since been undertaken on additional waste types, and this resulted in another update in 2014.

It should be noted that erosion modelling is conducted on the conservative assumption that slopes are not vegetated. However, vegetation is expected to establish on all slopes, further reducing the erosion potential.

<sup>&</sup>lt;sup>11</sup> Rio Tinto Iron Ore (WA), Landform Design Guidelines, July 2014, RTIO-HSE-0015708

### 19.1.2 West Angelas erosion risk

A significant fraction of the West Angelas mineral waste is comprised of geological units that are generally classified as being of high or moderate erodibility (e.g. detrital material, shales) with the more competent Banded Iron Formation geology that is common elsewhere in the Pilbara present in significantly lower proportions. However, there is a significant proportion of hydrated material, which is classified as having low erodibility.

West Angelas waste dump rehabilitation designs are therefore considered as conservative, adopting one or more of the following approaches:

- Construction of 'berm and batter' slopes to prevent excessive surface water flows down the slope;
- Reduction of slope angles from angle of repose (~37 degrees) to 18-20 degrees;
- Restriction of individual lift heights (i.e. the vertical distance between berms) in some cases to 5 m, which is the height recommended for slopes of this angle based on laboratory testing of the dominant material types at West Angelas and subsequent landform evolution modelling;
- Stockpiling of hydrated material to apply to the surface of waste dumps prior to rehabilitation, to enable
  a greater lift height of up to 20 m; and/or
- Selective dumping of material during operations to ensure that more competent waste types are concentrated on the surface of the dump.

Trials to date appear to illustrate that West Angelas waste dumps may be less susceptible to erosion than is predicted through the landform evolution modelling based on laboratory tests.

A field trial was conducted in 2006 to measure erosion rates simulating rain and overland flows applied to experimental plots, and measurements made of runoff and sediment. This information was then used to provide input data for landform evolution modelling. Recommendations arising from this work suggest that more typical rehabilitation '20/20/10' designs applied elsewhere in the Pilbara (20 m lift height, 20 degree slope, 10 m berms) could also be appropriate for this site. These specifications are less conservative than those arising from laboratory testing but may account for processes such as self-armouring of surface materials that are not as effectively measured in the laboratory.

Progressive rehabilitation trials have been conducted on Deposit A South and North (East) waste dumps in 2011/2, with a single batter rehabilitated on one section of each dump. The South WD batter ranged in height from 14-21 m, and had an average gradient of 16 degrees. The North WD had maximum batter heights of 10-12 m. Both slopes are performing much better than expected from an erosion perspective, with few gullies evident. With the exception of one gully at South Dump (Figure 28), they appear to now be stable and supporting good vegetation growth.

The performance of these rehabilitation trial areas was evaluated in 2016. Findings and recommendations included:

- The unstable gully in South Dump is currently eroding at a rate of approximately 25 t/ha/year, which is
  well in excess of the target maximum 5 t/ha/year erosion rate, and is possibly explained by a number of
  factors including high average gradient (17-19 degrees) in this area, a complex S-shaped profile rather
  than a linear slope, and topsoil potentially applied too thickly;
- All other sections of the rehabilitated slopes are exhibiting erosion rates lower than the target maximum erosion rate;
- Further erodibility testing is warranted on West Angelas waste materials;
- The recommendations arising from the 2006 study were based on achieving different erosion thresholds than are targeted today, and should therefore be considered obsolete; and
- Lift heights of ~12-15 m and gradients of <16 degrees appear to produce sufficiently stable batter profiles.

Based on the results of these field trials, rehabilitation design specifications are currently being reviewed.



Figure 28: Aerial view of West Angelas Deposit A South Waste Dump

#### 19.2 Management of waste dumps within zones of geotechnical instability

The Deposit A South Dump (Figure 8) and Deposit E South Dump (Figure 9) have minor intersections with the preliminary zone of instability defined by the default method prescribed by the DMP. However, it should be noted that:

- The zone of instability polygons may reduce in size following the outcomes of geotechnical evaluation as the current polygons are derived from default methodology documented in DMP guidelines;
- Waste material that is stored within these dumps will be utilized to backfill pits to a level that prevents the formation of pit lakes, and the dumps can therefore be reshaped if required to ensure that they are fully outside of the defined zone;
- In addition to these free-standing waste dumps, the Deposit A West Pit North backfill area is effectively
  a waste dump that has been constructed so as to straddle the pit edge so that half the dump is inside
  the pit and half is outside of it. The dump itself will therefore provide sufficient buttressing to the pit wall
  that geotechnical stability in this area is not a significant risk. The area will be rehabilitated as if it were
  a free-standing waste dump;
- No other current or proposed waste dumps intersect zones of instability around pits, and significant stand-offs have been adopted for recent and future mining areas (Deposits C, D, F and G); and
- There is potential for a cutback to occur in the Deposit A pit, which may result the pit moving closer to the South Dump (indeed it is possible that the cutback will extend the pit edge into the current dump footprint). Should this occur then the situation will be re-evaluated and portions of the waste dump removed and returned into the pit if required.

### 19.3 Management of inadvertent public access

The likelihood of inadvertent public access to the mining area is considered to be low for several reasons:

- West Angelas is situated in a remote location, with no population centres or public roads in the immediate vicinity;
- There are no adjacent pastoral stations or Aboriginal communities;
- The final landform will not contain any features such as pit lakes that would attract visitors;
- All infrastructure is proposed to be removed; and
- Regional topography is rugged from most directions to the site (although less rugged to the west in the direction of Great Northern Highway).

However, it is recognised that there is a possibility of public access if:

- Local cultural heritage sites need to be made accessible to Traditional Owners;
- Roads and tracks to the site are not properly closed; and/or
- Off-road vehicles travel to the site from the west (i.e. from the direction of Great Northern Highway)

Vehicular access to the site is currently via the private West Angelas Access Road, which comes off the public Great Northern Highway and enters the site from a north/northeast direction. The road is approximately 30 km in total length, but passes relatively close to Deposit B pits approximately 15 km off the public highway. In addition, there is a significant unsealed road leading into the site from the north and numerous tracks in the area.

Although there are currently no significant access routes entering the site from the south or west, several tracks have been installed in these areas to facilitate exploration activities. Terrain is rugged to the south and west of the site, and the potential for alternative vehicular access routes (including off-road vehicles) is limited to current tracks.

In order to mitigate the risk of inadvertent public access, the following conceptual measures are proposed, with details to be agreed with the Department of Mines and Petroleum Resources Safety Division as the site approaches closure:

- Rehabilitation of tracks that are not required for monitoring and/or maintenance post-closure, and installation of physical barriers (e.g. earthen bunds) where appropriate to prevent access;
- Installation of a locked gate on the main access road (and the alternative unsealed access road if it is
  required to remain post-closure) for the duration of the post-closure monitoring and maintenance
  period;
- Rehabilitation of all access roads prior to relinquishment and installation of physical barriers (e.g. earthen bunds), unless the State wishes the roads to remain accessible for whatever reason; and
- A review of the potential for visitors to inadvertently access the site, and installation of additional control measures, including abandonment bunding around pits, where appropriate.

At this stage there is uncertainty about the precise location of final pit shells for current deposits, and the potential for further unapproved deposits to be developed around those that currently exist. Precise abandonment bund locations have therefore not been proposed, but they will:

- be designed in accordance with the DMP guideline *Safety Bund Walls Around Abandoned Open Pit Mines* unless an alternative design is approved by the DMP;
- be placed outside of the zone of instability around pit walls;
- be constructed with consideration of the implications for local site drainage, and particularly giving consideration to associated impacts to cracking clay ecological communities; and
- be constructed fully around pit edges unless agreement is reached with the DMP that the risk of
  inadvertent access is sufficiently low in specific areas (e.g. due to natural topography, or due to the
  presence of barriers in other locations).

Abandonment bunds will be incorporated into the construction design for Deposits C and D, with a view to potentially installing them prior to the commencement of operations. If construction is delayed for whatever reason, their construction will be scheduled in the mine plan.

# 19.4 Management of fibrous mineral waste

Some isolated occurrences of fibrous material have been intersected at West Angelas, and a larger volume of material has been classified as 'potentially fibrous' based on conservative geological interpretation rather than confirmed occurrence. Control measures are employed during operations to reduce the potential health risk posed by exposure to this material in line with the Iron Ore (WA) Fibrous Minerals Management Plan. Material that is classified as 'designated fibrous' or 'potentially fibrous' is stored preferentially in-pit, but otherwise in ex-pit waste dumps and encapsulated with a minimum of 2 m non-fibrous material. It should also be noted that the likelihood of public exposure to fibrous minerals will be further reduced at West Angelas due to its remote location, and the installation of abandonment bunds to prevent inadvertent public access.

No Potentially Hazardous or Designated Hazardous areas are demarcated in pit walls that will form the West Angelas post-mining landform and no geological units identified with a high risk of containing potentially fibrous materials are proposed to be mined in the future.

Potentially fibrous material has been stored in Deposit A North Waste Dump (Figure 29). Detailed rehabilitation designs are currently being developed to support progressive rehabilitation of several faces of the dump in the near future, and will take into account that potentially fibrous material needs to remain encapsulated in the final design.

Deposit B East Waste Dump has also been designated as a storage location for potentially fibrous material in the future, but specific storage locations within the dump are yet to be determined.



Figure 29: Potentially Fibrous Material Storage at Deposit A North Waste Dump

# 19.5 Drainage diversion design and management

There are two drainage diversions constructed at the site (Deposit B and Deposit F), and diversions will also be constructed to facilitate mining at Deposit C and D.

### 19.5.1 Deposit B Diversion

A diversion has been construction for an unnamed ephemeral creek in order to facilitate mining of Deposit B. The original creek location is shown in Figure 30.

In order to avoid capture of flows into the Deposit B pit, a diversion berm has been constructed which directs flows to a diversion channel (Figure 31). The berm and diversion are intended to be permanent structures.

The diversion berm is approximately 320 m in length, 200 m wide, and has a maximum height of 8.5 m. Since the berm is intended to be a permanent structure, and has been designed to contain events up to the 2000 year ARI event. Modelling suggests that the berm would be overtopped during a PMF event, and would need to be raised an additional 3.1 m in order to contain such an event. The value of raising the berm to this level will be assessed as the site approaches closure, by which time there should be improved validation of model parameters.

The diversion channel has a base width of 18 m, which increases to 23 m at the top, and runs for a total length of 2.1 km. The channel is relatively wide, which is intended to reduce flow velocities and associated scouring. The channel flows under a haul road, and two 1200 mm culverts have been constructed to facilitate this. The haul road and culverts will be removed at closure, but no further closure works are currently proposed. The diversion channel is rock-lined, and rehabilitation is not proposed.

The performance of the channel will be evaluated during operations, and the closure strategy will be reassessed as the site approaches closure.



Figure 30: Original location of ephemeral creek impacted by Deposit B development



Figure 31: Deposit B diversion berm and channel

### 19.5.2 Deposit F Diversion

One of the Deposit F pits (F2 pit) intercepts an unnamed ephemeral creek. In order to manage flows, a diversion and levee has been placed upstream of the pit to direct flows eastwards into the Weeli Wolli Creek catchment, as shown on Figure 32.



Figure 32: Deposit F diversion

The diversion and levee is 3.4 km in length and ranges in height from 3.5 m to 5.6 m. It is 15 m wide at the base, tapering to 3 m wide at the top.

Hydraulic modelling indicates that flow velocities in this region are relatively low, not exceeding 2 m/s during a 2% AEP flood event. On this basis, the risk of scour and sediment transportation along the alignment is considered low. However, scour protection has been incorporated into the design to provide additional protection to the structure.

The diversion and channel are planned to be retained post-closure.

#### 19.5.3 Deposit C and D Diversions

Pre-mining flood modelling completed for Deposit C indicates (Figure 33), without flood protection, water from Turee Creek East would flow into Deposit C (Pit 3). Creek capture would cause a significant reduction of flow through capture of Turee Creek East flows in Deposit C could have an unacceptable impact on the downstream Karijini National Park.

Therefore, to manage surface water flows from the Turee Creek East tributary intercepted by Deposit C, a 1% AEP capacity diversion channel is proposed to the north of Deposit C (Pit 3). The 3 km diversion channel, referred to as the Turee Creek East Realignment Diversion, will be designed to redirect the surface water flows which would otherwise be captured by Deposit C northwards, to maintain the continuation of natural surface water flows in Turee Creek East during operations.



Figure 33: Maximum extent of 1% AEP flood event under existing conditions at Deposit C

Similarly, with no flood protection, water from Turee Creek East South would flow into Deposit D (Pit D3). To manage flows from the Turee Creek East South tributary intercepted by Deposit D, a 2% AEP capacity diversion channel is proposed to the north and west of Deposit D (Pit 3). The 2.7 km diversion channel will redirect surface water flows, which would otherwise be captured by Deposit D, around the north and west of Pit D3 to maintain the continuation of natural surface water flows in Turee Creek East.


Figure 34: Maximum extent of 2% AEP flood event under existing conditions at Deposit D

Whilst closure landform modelling has not been completed at this stage of development, it is anticipated that both the Turee East Realignment Diversion and the Turee Creek East South diversion channel will remain in at closure in an appropriate capacity to maintain the hydrological values of the West Angelas area and Karijini National Park.

## 19.6 Maintenance of Cracking Clay ecological community values

There are numerous areas of *Themeda* grassland cracking clay Priority Ecological Communities (PEC) at the West Angelas site, in addition to several other cracking clay communities with different vegetation assemblages that have not been listed as PEC.

The PEC areas have been identified as exclusion zones and controls are in place to prevent unapproved direct disturbance during operations and closure. This includes direct disturbance that could occur as waste dump footprints are expanded during rehabilitation in order to create stable landforms.

Notwithstanding controls against direct disturbance of PEC areas, there is the potential for indirect impacts resulting from changes to surface water flow regimes caused through the altered landform. This is a risk that will need to be evaluated when final landscaping profiles have been developed, and passive mitigation measures adopted where appropriate.

Non-PEC cracking clay communities are identified internally as 'restricted' access zones which limits the potential for disturbance, but disturbance is possible from time to time.

## 19.7 Groundwater drawdown

Numerical groundwater recovery modelling has been undertaken for Deposits A, B and E. The modelling indicates that recovery will be slow, and that levels will not rebound to pre-mining levels in all locations.

Data presented in previous versions of the closure plan have assumed that pits will be backfilled to above pre-mining water table levels, as per the key characteristics of the original West Angelas proposal. This was adjusted by the Deposit F and A West expansion proposal, which was assessed on the basis that pits would be backfilled to a level that prevents the formation of a permanent pit lake.

The minimum backfill level that would be required to avoid the formation of a permanent pit lake has not yet been determined, but is expected be a lower elevation than the pre-mining water table as losses of water through evaporation and infiltration are taken into account. There would be some degree of permanent groundwater drawdown around the pit in this scenario, but the spatial extent has not been defined.

The proposed Deposits C and D are closer to Karijini National Park than existing mining areas and groundwater abstraction for the purposes of ore extraction is expected to propagate within Karijini National

Park boundary. Drawdown of the groundwater beneath potentially groundwater dependent vegetation (approximately 1 to 6 meters) within the Park is expected to continue to extend after the cessation of dewatering.

Depth to groundwater also suggests that recharge of aquifer is limited. Given the limited recharge is conservatively assumed that pre-mining groundwater elevation will not occur. However, data suggested that recharge via surface water events within the vicinity of Karijini National Park could potentially mitigate the effect of drawdown in the area. Therefore, groundwater drawdown is not expected to have any significant impact on the ecohydrology of the Park nor impact on the inherent values of the Park.

As groundwater in the West Angelas region has limited alternative beneficial use, and significant vegetation in the area (e.g. the Cracking Clay PEC) is not reliant on groundwater, a permanent localised lowering of the groundwater table is not considered to be significant, and closure strategies have not been developed to manage the issue.

New information will be assessed as it arises and if required the predicted consequence of groundwater drawdown will be elevated. If required closure strategies will be explored to actively manage this risk.

# 20. Actions to address issues and risks

A West Angelas closure risk assessment has been undertaken (Appendix D), resulting in the development of actions to mitigate risk (Table 19).

The risk assessment was conducted using a framework consistent with that provided in the Leading Practice Sustainable Development in Mining Handbook on *Risk Assessment and Management.*<sup>12</sup> A list of threats was compiled with consideration given to all of the potential issues identified in this chapter, and the most serious credible threat scenarios for each issue was identified. Risk assessment assumed that mine operations and closure are implemented in accordance with current strategies, and taking into account the controls already in place to mitigate risk. These were then evaluated using a standard likelihood and consequence matrix, and classified according to the following scale:

- Class IV the most serious threats that require action
- Class III serious threats that require active mitigation
- Class II threats that require monitoring, but not necessarily action
- Class I threats that do not require action

<sup>&</sup>lt;sup>12</sup> Department of Industry Tourism and Resources, *Leading Practice Sustainable Development in Mining Handbook: Risk Assessment and Management,* 2008

Risk scenario	Identified mitigation actions	Indicative timing		
Fibrous materials are re-exposed post- closure, creating a public health risk	1. Evaluate closure landform designs with respect to managing the potential for exposure/re-exposure of fibrous materials, and incorporate design changes where required.	1. Report progress in next closure plan update		
A permanent pit lake forms at the base of a mine void, due to inaccurate groundwater recovery information and/or high surface water flow contribution, and leads to an increase of invasive species	1. Undertake groundwater recovery modelling for all pits	1. Report progress in next closure plan update		
Geotechnical failure of a pit wall causes a waste dump to collapse into a pit void, requiring rehabilitation rework after the active post-closure maintenance period	<ol> <li>Develop rehabilitation designs for waste dumps that are currently located within zones of instability (Deposit A South Dump and Deposit E South Dump) that ensure these dumps are outside the zone of instability</li> </ol>	1. Report progress in next closure plan update		
Excessive erosion of waste dumps resulting in rehabilitation failure and downstream sediment impacts	<ol> <li>Develop new rehabilitation designs for existing waste dumps (e.g. Deposit A) that may not have been constructed to readily facilitate stable rehabilitation slopes</li> <li>Undertake further site specific waste characterisation to better define dump erosion potential</li> </ol>	<ol> <li>Report progress in next closure plan update</li> <li>Report progress in next closure plan update</li> </ol>		
Post-closure access of the mine area leads to a third party injury or fatality	<ol> <li>Confirm abandonment bund locations and timing of construction</li> </ol>	1. Report progress in next closure plan update		
Grading of the landscape around cracking clay communities changes surface water flow paths or sedimentation, resulting in impacts to ecosystem health	<ol> <li>Evaluate the final landform design with respect to the potential for impacts to cracking clay communities</li> <li>Undertake trials to evaluate the potential to translocate cracking clay communities that may be disturbed during operations or post-closure -</li> </ol>	<ol> <li>Defer until the site is approaching closure</li> <li>Undertake when opportunities arise</li> </ol>		
Landscape and ecosystem changes impact cultural heritage values in the area	<ol> <li>Investigate the potential for cultural heritage values to be impacted post-closure, and evaluate the implications of impacts if they arise.</li> <li>Develop closure strategies to maintain cultural heritage values</li> <li>Ensure consistency between Cultural Heritage Management Plan and Closure Plan</li> </ol>	<ol> <li>Managed and reported internally through Cultural Heritage Management Plan</li> <li>Managed and reported internally through Cultural Heritage Management Plan</li> <li>Internal action – closure plan will be updated as required</li> </ol>		

# **CLOSURE IMPLEMENTATION**

Rio Tinto uses closure domains to group areas with common features, rehabilitation and decommissioning requirements at closure. Detailed closure strategies for the rehabilitation and decommissioning of individual closure domains, beyond those of current standard management practices, will be documented as the site approaches closure. The closure measures identified below consider the methods used to manage key risk as discussed in the previous section.

# 21. Closure domains

Closure domains are used to group areas with common features, rehabilitation and decommissioning requirements. Figure 35 illustrates the closure domains that have been established for West Angelas (noting that Deposit A West and G are conceptual at this stage, and therefore only indicative pit and waste dump locations are shown). Also note that the current Deposit E East waste dump has not been identified as a closure domain on the basis that it will be consumed by Deposit F West waste dump. West Angelas domains include:

- **Pits**: Includes currently operating, developing or proposed pits associated with Deposits A, A West, B, C, D, E, F and G;
- Pit Backfill; Includes BWT pits are progressively being backfilled or will be backfilled at closure.
- **Inert waste dumps**: Includes inert external waste dumps and long term low grade material stockpiles that are not currently planned to be utilised in processing;
- Fibrous waste dumps: Includes external waste dumps that contain designated or potentially fibrous mineral waste;
- Landfill: Refers to site putrescible landfill including general waste;
- Diversions: Refers to surface water diversions that have been constructed to facilitate mining;
- Infrastructure: Refers to areas where items of infrastructure are located (not shown in Figure 35); and
- **Other Disturbed areas**: All areas of disturbance that are not categorised by any of the above landform domain categories. This domain has been broken down into 'high disturbance', 'medium disturbance' and 'low disturbance' sub-domains, based on the amount of earthworks that will be required during final landscaping, to allow for more accurate closure cost estimation.

# 22. Closure implementation strategies

Proposed closure strategies for each of the closure domains are included in Table 20.



Figure 35: West Angelas closure domains (pits and waste dumps only)

Table 20: West Angelas general area implementation strategies by closure domain

Domain	Aroo		
Dit		1 Dite maybe partially backfilled where appartually exists	
1 K	AWT pits	1.	
		2.	recommended following a review of public safety risks.
		3.	No further rehabilitation will be conducted within pit voids unless the backfill level is within 10 m of the ground surface.
Pit - Backfill All deposits and internal backfill areas, with the exception of Deposit A West Pit North backfill		1.	Backfill pit to at least 2 m above the long-term predicted groundwater recovery level. Minimum backfill levels for Deposits A, B and E are presented below (although these levels may be reduced depending on the outcomes of refined groundwater recovery modelling), with other pits to be ascertained once groundwater recovery modelling is complete:
		2.	Deposit A CEPN: 612 mRL
		3.	Deposit A CEPS: 632 mRL
		4.	Deposit B1: 609 mRL
		5.	Deposit B2 and B3: 628 mRL
		6.	Deposit E: 652 mRL
		7.	Backfill level in other pits yet to be confirmed
		8.	Install abandonment bunds around pit perimeters if this is recommended following a review of public safety risks.
		9.	No further rehabilitation will be conducted within pit voids unless the backfill level is within 10 m of the ground surface.
Waste Dump - Inert	Deposit A South WD Deposit A West Pit North backfill	1.	Waste dump construction and rehabilitation design specifications are presented in Appendix E, noting that design specifications are currently under review.
	Deposit B Low Grade Deposit C&D WD Deposit D WD Deposit E South WD Deposit E West WD Deposit F West WD Deposit F Low Grade Deposit F East WD	2.	Hydrated material, which is known to be a low erodibility material, is being stockpiled for use as a capping layer on waste dump slopes where required.
		3.	Apply a 200 mm layer of topsoil (or subsoil where topsoil is unavailable).
		4.	Deep rip the surface on the contour and seed using appropriate native species.
Waste Dump -	Deposit A North WD	1.	Segregation and encapsulation of fibrous material
FIDIOUS	Deposit B East WD	2.	Reshaping outer slopes to appropriate angles/profiles based on design criteria suitable for waste type
		3.	Application of subsoil/topsoil
		4.	Rip and seed using appropriate native species.
Landfill	Landfill	1.	Cap landfill with a layer of inert material to a minimum thickness of 2 m
		2.	Rehabilitate final surface in accordance with standard procedures (as per infrastructure areas)

Domain	Area	Clo	losure measures	
Diversions	Deposit B diversion Deposit F diversion Deposit C diversions Deposit D diversions	1.	As a general rule, where a drainage line has been diverted to facilitate mining activity, no attempt will be made to restore the original drainage configuration. Rehabilitation will be in accordance with the information presented in Section 19.5.	
Other areas of disturbance	Areas of disturbance that are not captured by any of the above domain classifications, including infrastructure areas	1.	. Retain or remove infrastructure in accordance with State Agreement requirements	
		2.	<ul> <li>Undertake contaminated sites evaluation and clean up if required</li> </ul>	
		3.	<ul> <li>Where infrastructure requires removal, remove all structures and footings that is above surface or within 1 m of the final land surface</li> </ul>	
		4.	<ul> <li>Drain pipelines and remove hazardous materials (from pipelines and elsewhere across the site) in accordance with Controlled Waste Regulations</li> </ul>	
		5.	<ul> <li>Actively seek reuse and recycling opportunities for decommissioned infrastructure</li> </ul>	
		6.	Dispose of inert materials are not retained, reused or recycled in an inert landfill area (may be a used pit area) and then cap with at least 2 m of inert material	
		7.	<ul> <li>Where linear infrastructure is removed, reinstate drainage lines where appropriate</li> </ul>	
		8.	<ul> <li>Rehabilitate final surface in accordance with standard procedures, which includes:</li> </ul>	
			<ul> <li>add a layer of topsoil where available and appropriate</li> </ul>	
			<ul> <li>deep rip the surface where required to address compaction</li> </ul>	
			<ul> <li>revegetate with an appropriate mix of species of local provenance</li> </ul>	

# 23. Unexpected closure

The closure implementation schedule may be influenced by factors outside of the current mine plan. These factors include:

- suspension of operations under care and maintenance; this could occur if production costs exceed product value e.g. due to commodity price changes;
- unexpected closure; this could occur if there was major change in global demand for iron ore; and
- future proposals; these could occur if iron ore deposits of appropriate quality are identified adjacent to the existing deposits.

## 23.1 **Temporary care and maintenance**

In the event of temporary closure, measures will be undertaken to transfer the site from operations into a care and maintenance regime and relevant authorities notified. A care and maintenance plan will be developed prior to the care and maintenance period which demonstrates how on-going environmental obligations associated with the site will continue to be met during the period of care and maintenance.

## 23.2 Early permanent closure

Whilst Robe considers the risk of unexpected closure to be minimal, there are numerous factors that could force early closure of one or several sites. Even if some level of contraction were to occur, it is reasonable to assume that the company would continue to operate in the Pilbara and that it could continue to manage closure of its sites. It should be noted that Robe is one group within the global Rio Tinto group of companies, which further mitigates this risk.

The West Angelas closure plan will naturally become more detailed as time progresses, but may not be of sufficient detail to facilitate closure implementation if the site closes unexpectedly. This would be the case particularly if the proposed closure strategies rely on the full mining sequence, and need to be revised accordingly. If sudden and unexpected closure occurs, the site would effectively be placed on a period of care and maintenance whilst studies and plans are developed to facilitate effective closure implementation. Final completion criteria would also be agreed with stakeholders during this period. Closure could be expected to be delayed by several years if production ceases unexpectedly.

Notwithstanding this, the most likely early closure scenario would involve a decision to cease production made several years in advance of the event, which would provide time for the closure plan to be updated sufficiently to facilitate more timely closure implementation.

# **CLOSURE MONITORING AND MAINTENANCE**

# 24. Closure monitoring program

The primary purpose of closure monitoring is to assess whether closure objectives have been met for West Angelas. A specific monitoring program will be finalised as the site approaches closure, and this current plan outlines the principles that will be employed rather than specific details.

## 24.1 **Phases of monitoring**

For the purposes of this plan, monitoring is assumed to be conducted in several phases including:

- Baseline monitoring, which is conducted as operations expand into new mining areas. Results that are relevant to closure are summarised in the environment knowledge base;
- Operational monitoring, which occurs throughout the life of the mine, in line with regulatory requirements and the Rio Tinto operational standards. Results that are relevant to closure are incorporated in the environment knowledge base when it is reviewed;
- Pre-closure monitoring, which occurs as the site approaches closure to underpin assessment of postclosure performance;
- Closure monitoring, which is conducted during the period of active site closure (approximately two years following the cessation of mining); and
- Post-closure monitoring, which is conducted on a regular basis until either:
  - There is a demonstration that closure objectives have been met and that the site is able to be relinquished; or
  - Parameters being monitored reach a steady state.

This plan considers pre-closure, closure and post-closure monitoring.

## 24.2 Indicative monitoring program

The monitoring program will be finalised during development of a Final Decommissioning Plan as the site approaches closure. Specific and appropriate monitoring will be conducted to ensure data is obtained to allow assessment of performance against completion criteria (Section 8).

The monitoring programme is likely to contain specific monitoring of the following key areas, as a minimum.

## 24.2.1 Rehabilitation monitoring

The purpose of the rehabilitation monitoring program is to evaluate successional development of rehabilitation areas and thereby provide useful feedback for the improvement of rehabilitation techniques and to help assess progress towards long term rehabilitation objectives.

Rehabilitation monitoring also provides vital information which can be used to set realistic and achievable completion criteria. This can be achieved by examining changes in key parameters over time, and by comparing results from the rehabilitation with those from corresponding reference sites. Reference sites, also known as Controls or Analogues, are positioned within local areas of native vegetation.

Habitat characteristics are recorded by quadrat at intervals along transects at established in rehabilitation and associated reference sites. Qualitative assessment of erosion, soil surface, perennial vegetation cover, species richness, weeds and general condition is also recorded.

The current monitoring programme includes:

- number of plants by species;
- percentage cover by species;
- bare areas in quadrat;
- percentage of perennial cover;

- percentage of spinifex cover;
- percentage of grass cover (excluding spinifex);
- percentage of native perennial shrub cover (0.5 m to 2 m);
- percentage of litter cover;
- percentage of tree cover > 2 m;
- presence of annuals; and
- presence of weeds, and species.

Transects are also reviewed as a whole to record:

- number of logs (>10 cm diameter and >30 cm long);
- number of rocks (>15 cm diameter);
- presence of scat;
- presence of ants,;
- general animal sighting (including tracks, burrows and nests);
- flowering and fruiting species;
- extent of grazing; and
- if burnt since last monitoring.

Erosion monitoring involves the examination of transects for the number of rills and gullies, recording their width and depth. These measurements are compared over time to determine if the landform has stabilised; for example erosion rates are within the accepted completion criteria range or rill and gully geometry is similar to the surrounding landscape. If a landform fails to stabilise, further management / intervention will be investigated.

Rehabilitation monitoring occurs on a scheduled basis, aimed at establishing trends for the locations return to self-sustaining status. The rehabilitation development is compared to the reference site values. Data analysis is undertaken to assess progress towards an acceptable outcome.

## 24.2.2 Water monitoring

Water monitoring during closure will focus on confirming groundwater recovery and pit lake modelling predictions, and identification of any AMD issues. A specific program of monitoring will be developed prior to decommissioning.

## 24.3 Heritage surveys

Heritage assessments are undertaken prior to closure to ascertain potential cultural heritage impacts of closure implementation, and inform the development of alternative strategies if required. Assessments are also undertaken post-closure to confirm that implementation has been undertaken in an appropriate manner.

## 25. Post-closure maintenance

Post closure, maintenance will continue as required until it is determined that the closure objectives have been met or it is otherwise agreed with Government to allow relinquishment of the site.

# FINANCIAL PROVISION FOR CLOSURE

Rio Tinto considers specifics of the closure cost estimate to be commercially sensitive information. This section outlines the general process used to develop the closure cost estimate.

# 26. Principles of Rio Tinto closure cost estimation

Closure cost estimates are determined based on methods outlined in the Rio Tinto Closure Standard and the Rio Tinto Accounting Policy. Closure costs are considered in two formats:

- a Present Closure Obligation (PCO) which is indicative of costs associated with closure of the mine given its current footprint, this accounts for the progressive development of a site over time; and
- a Total Projected Closure (TPC) cost which predicts the cost (in current terms) associated with closure at the end of the life of the mine. The TPC includes areas that are not currently approved, but that feature within the life of mine plan and that are considered likely to be developed in the future.

The cost estimates consider the following components<sup>13</sup>:

- decommissioning (ie removal of infrastructure)<sup>14</sup>;
- final landform construction;
- rehabilitation and biodiversity management;
- heritage management;
- workforce management (ie training costs and redundancy payments)15;
- monitoring costs;
- costs associated with updating the closure plan to facilitate effective closure implementation;
- costs associated with undertaking a final shutdown of operations;
- allowance for failed rehabilitation or pollution that may necessitate rework of rehabilitation areas;
- assignment of indirect costs in accordance with Rio Tinto Accounting Policy; and
- a contingency factor.

<sup>&</sup>lt;sup>13</sup> Costs associated with decontamination are assessed during closure plan development but are costed separately as they are classified as operating costs, not closure costs.

<sup>&</sup>lt;sup>14</sup> The decommissioning cost estimate assumes that infrastructure will be demolished and buried on site. The site is sufficiently remote that deconstruction for the purposes of materials salvage and recycling is likely to be cost prohibitive. However; opportunities for salvage and recycling will be sought as the site approaches closure.

<sup>&</sup>lt;sup>15</sup> Workforce management costs have only been included in the TPC.

# 27. Closure cost estimation methods

The closure cost estimation methodology is based on methods outlined in the Rio Tinto Closure Standard and Rio Tinto Accounting Policy, with the level of accuracy increasing as the site approaches closure<sup>16</sup>. The closure cost estimates are conducted based on the most recent information of mine plans and infrastructure. Closure costs estimate are generally undertaken by specialist external consultants. The PCO estimate for each site is revised on an annual basis to account for incremental mine development during the year. The TPC estimate is revised whenever a formal closure plan review is conducted (usually 3-yearly) to capture any changes to life of mine design. As part of Rio Tinto assurance processes these costs are audited by external financial auditors annually to ensure adequate closure provisions are maintained.

Note that for commercial reasons the actual estimate is not documented in this closure plan.

<sup>&</sup>lt;sup>16</sup> The level of accuracy applied to Rio Tinto iron ore estimates is as follows:

<sup>•</sup> greater than 10 years from closure: ±30%;

between 10 years and 5 years from closure: ±20%; and

less than 5 years from closure: ±15%.

# MANAGEMENT OF INFORMATION AND DATA

# 28. Data and information management

## 28.1 Iron Ore Document Management System (IODMS)

Rio Tinto operates a comprehensive document management system, with electronic records of all key information and data. The document system, known as Iron Ore Document Management System (**IODMS**) is linked to other business units within the Rio Tinto group of companies, and processes are in place to ensure that the data contained within this system is appropriately backed up and protected. Each document stored within this system si given a unique document number which identifies the document and enables it to be accessed. This system will continue to operate following site closure, and all relevant data will be retained according to appropriate data retention requirements.

An audit will be conducted prior to closure to ascertain whether there is any additional information stored in hard copy form at the site. Such data will be scanned and entered into IODMS to ensure that it is appropriately retained post-closure.

## 28.2 Closure knowledge base

The closure knowledge database is a knowledge management process designed to bring closure related research and monitoring outcomes together into one searchable location. It uses a single entry form to capture where the report is stored, and how and where the research can be applied for all new ongoing and completed closure related studies. This information is then managed by the Closure team within a secure database.

## 28.3 EnviroSys

EnviroSys is an environmental database that is used by Rio Tinto to manage environmental and hydrogeological data. The tool is used to store, monitor and analyse those parameters and report trends on data collections.

Data collected currently includes:

- groundwater biological, chemical, field, levels, production;
- marine water biological, chemical, field;
- soil chemistry;
- surface water biological, chemical, field, levels, production;
- tonnes and moisture;
- water meters; and
- weather (rainfall, temperatures etc.).

EnviroSys is used to support the building of closure knowledge bases, as well as ensure compliance with operating licenses pertaining to data management. At closure this data would be appropriately stored to allow for review of post closure completion criteria.

## WEST ANGELAS CLOSURE OBLIGATIONS REGISTER

# Legal Obligations

Ministerial Statement 970				
Condition No.	Closure conditions			
9-1	The proponent shall ensure that the mine is closed, decommissioned and rehabilitated in an ecologically sustainable manner, consistent			
	with agreed post-mining outcomes and land uses, and without unacceptable liability to the State of Western Australia.			
9-2	The proponent shall prepare a Mine Closure Plan for the West Angelas Iron Ore Project			
9-3	The Mine Closure Plan required by condition 9-2 shall:			
	(1) when implemented, manage the implementation of the proposal to meet the requirements of condition 9-1;			
	(2) be prepared in accordance with the Guidelines for Preparing Mine Closure Plans, June 2011 (Department of Mines and Petroleum and			
	Environmental Proection Authority) or its revisions; and			
	(3) be to the requirements of the CEO on advice from the Department of Mines and Petroleum.			
9-4	Within 12 months of commissioning of additional mine pits or as otherwise agreed by the CEO the proponent shall implement the			
	approved Mine Closure Plan and continue implementation until otherwise agreed by the CEO.			
9-5	Revisions to the Mine Closure Plan may be approved by the CEO on the advice of the Department of Mines and Petroleum.			
9-6	The proponent shall implement revisions of the Mine Closure Plan required by condition 9-5.			

Mining Act 1978				
Tenement No. G47/1235				
Condition No.	Closure conditions			
12	(The lease is issued subject to) at the completion of operations, all buildings and structures being removed from site or demolished and			
	buried to the satisfaction of the Executive Director, Environment Division, DMP.			
15	(The lease is issued subject to) at the completion of operations or progressively where possible, all access roads and other disturbed			
	areas to be covered with topsoil, deep ripped and revegetated with local native grasses, shrubs and trees to the satisfaction of the			
	Executive Director, Environment Division, DMP.			

# WEST ANGELAS CLOSURE OBLIGATIONS REGISTER

Legal Obligations

Condition No.	Closure conditions		
13	(The lease is issued subject to) at the completion of operations, all buildings and structures being removed from site or demolished and		
	buried to the satisfaction of the Executive Director, Environment Division, DMP.		
16	(The lease is issued subject to) at the completion of operations or progressively where possible, all access roads and other disturbed		
	areas to be covered with topsoil, deep ripped and revegetated with local native grasses, shrubs and trees to the satisfaction of the		
	Executive Director, Environment Division, DMP.		

Tenement No. L47/41					
Condition No.	Closure conditions				
13	On the completion of the life of mining operations in relation to Miscellaneous Licence 47/71 the holder shall:				
	- remove all installations constructed pursuant to this licence;				
	- cover over all wells and holes in the ground to such degree of safety as shall be determined by the Inspector; and				
	- on such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or any other plant as shall				
	conform to the general pattern and type of growth in the area and as directed by the Inspector and properly maintain same until the				
	Inspector advises regrowth is self supporting.				
	Unless the Mining Registrar/Warden or Minister for Mines orders or consents otherwise.				

Tenement No. L47/52				
Condition No.	Closure conditions			
11	(The lease is issued subject to) at the completion of operations, all buildings and structures being removed from site or demolished and			
	buried to the satisfaction of the Executive Director, Environment Division, DMP.			
15	On the completion of operations or progressively where 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 outcome			
	agreed to the satisfaction of the Executive Director, Environment Division, DMP.			

Tenement No. L47/53	3
Condition No.	Closure conditions

## WEST ANGELAS CLOSURE OBLIGATIONS REGISTER

# Formal Commitments

Iron Ore (Robe River) Agreement Act 1964				
Clause No.	Closure obligations			
10 (e)	The parties agree with each other as follows: that on the cessation or determination of any lease license or easement granted hereunder by the State to the Company the improvements and things erected on the relevant land and provided for in connection therewith other than plant and equipment shall remain or become the absolute property of the State without compensation and freed and discharged from all mortgages and encumbrances and the Company will do and execute such documents and things (including surrenders) as the State may reasonably require to give effect to this projection. In the event of the Company immediately prior to such expiration or determination or subsequent thereto deciding to remove its locomotives rolling stock plant and equipment or any of them from any land it shall not do so without first notifying the State in writing of its decision and thereby granting to the State the right or option exercisable within three months thereafter to purchase at valuation in situ the said plant and equipment or any of them. Such valuation shall be mutually agreed or in default of agreement shall be made by such competent valuer as the parties may appoint or failing agreement as to such appointment then by two competent valuers one to be appointed by each party or by an umpire appointed by such valuers should they fail to agree.			

## WEST ANGELAS CLOSURE OBLIGATIONS REGISTER Relevant Legislation

Closure planning and implementation requires consideration of general legislative requirements beyond those that apply to a specific site. A list of potentially relevant legislation is provided below, but is not necessarily exhaustive. A comprehensive legal review will be required as closure approaches to ensure that all relevant legislative requirements are identified.

## Australian Commonwealth Legislation

Environmental Protection and Biodiversity Conservation Act 1999 Native Title Act 1993 Aboriginal and Torres Strait Islander Heritage Protection Act 1984 Workplace Relations Act 1996

## Western Australian State Legislation

**Environmental Protection Act 1986 Environmental Protection Regulations 1987** Environmental Protection (Controlled Waste) Regulations 2004 Environmental Protection (Unauthorised Discharges) Regulations 2004 Contaminated Sites Act 2003 Contaminated Sites Regulations 2006 Conservation and Land Management Act 1984 Mining Act 1978 Mining Regulations 1981 Parks and Reserves Act 1895 Rights in Water and Irrigation Act 1914 Wildlife Conservation Act 1950 Aboriginal Heritage Act 1972 Aboriginal Affairs Planning Authority Act 1972 Mines Safety and Inspection Act 1994 Mines Safety and Inspection Regulations 1995 Occupiers Liability Act 1985 Criminal Code Compilation Act 1913

## WEST ANGELAS CLOSURE OBLIGATIONS REGISTER **Relevant Guidelines and Standards**

Closure planning and implementation requires consideration of relevant guidelines and standards, some of which may have regulatory consequence through being referenced in regulatory documents. A list of key guidelines and standards that are routinely considered is provided below, but is not exhaustive due to the breadth of the closure planning discipline. This closure plan has been prepared so as to be considered with relevant content of these guidelines and standards.

Guideline or Standard	Author
Guidelines for the Preparation of Mine Closure Plans (2015)	Western Australian Department of Mines and Petroleum and
	Environmental Protection Authority
Leading Practice Sustainable Development Program for the Mining Industry -	Commonwealth Department of Industry Trade and Resources
Mine Closure and Completion (2006)	
Mine Rehabilitation Handbook (1998)	Minerals Council of Australia
Guideline for the Assessment of Environmental Factors: Rehabilitation of	Western Australian Environmental Protection Authority
Terrestrial Ecosystems (2006)	
Australian and New Zealand Guidelines for Fresh and Marine Water Quality	Agriculture and Resource Management Council of Australia and New
(2000)	Zealand and the Australian and New Zealand Environment and
	Conservation Council
Mine Void Water Resource Issues in Western Australia (2003)	Western Australian Water and Rivers Commission
Contaminated Sites guideline series	Western Australian Department of Environmental Regulation
Environmental Notes on Mining: Acid Mine Drainage (2009)	Western Australian Department of Mines and Petroleum
Environmental Notes on Mining: Waste Rock Dumps (2009)	Western Australian Department of Mines and Petroleum
Safety Bund Walls Around Abandoned Open Pit Mines (1997)	Western Australian Department of Industry and Resources
Global Acid Rock Drainage Guide (2014)	International Network for Acid Prevention
Australian Standard 2601: The Demolition of Structures (2001)	Standards Australia
Australian Standard 4976: The Removal of Underground Petroleum Storage	Standards Australia
Tanks (2008)	
Demolition Work Code of Practice (2015)	Safe Work Australia

# **APPENDIX B – COMMUNICATIONS REGISTER**

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
West Angelas Deposits A and B Environmental Review and Management Program	Summary of consultation outcomes arising from the ERMP (1999)	EPA advice provided for the Deposit A and B referral (relevant to closure) requested: - location and design of waste dumps have no impact on vegetation with high conservation value or cracking clay areas; - original drainage patterns be restored; and - supports the commitment to pit infilling required to prevent evaporation of groundwater bround to the surface by capillary rise in the soil cover.	Robe integrated these requests into its (then) Decommissioning and Rehabilitation Plan, which has since been superseded by this document.
West Angelas Deposit E development proposal	Summary of consultation outcomes arising from the proposal (which was not formally assessed by the EPA)	CALM avised that the mulga in the Deposit E area is significant	Internal approval processes are required for each parcel of new footprint disturbed, and impacts to areas of environmental significance (e.g. mulga communities) are considered in this process.
Update of MS514	EPA (October 2013)	EPA proposed the addition of a condition on MS514 requiring submission of a closure plan, and requested removal of Section 8.9 (Closure and Rehabilitation Mgt Plan) from the EMP to avoid duplication	The EMP no longer contains a section on Closure and Rehabilitation, as this is now addressed by this document.

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Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
OEPA Response to July 2014 closure plan	OEPA (November 2014)	The OEPA advised that it had sought advice on the July 2014 closure plan from the DMP, and that it could not be approved	Consultation was conducted on 11 February 2015 (see record below) to discuss these issues.
		until nine comments had been addressed:	
		1. Demonstration of a risk analysis process	
		2. Specificity of management controls	
		3. Inclusions of rehabilitation designs for the Deposit B long	
		term low grade stockpile	
		4. Consultation with the DMP	
		5. Given that the site is on vacant crown land close to Karajini	
		National Park, the return of a native ecosystem would be	
		supported, and acceptance of pastoralism as a final land use	
		would require consultation with relevant stakeholders.	
		6. Closure objectives do not encompass all aspects of the site.	
		7. Waste dumps appear to be within the zone of instability	
		around pits	
		8. Consultation with the DoW	
		9. Completion criteria do not address all aspects of the site.	
		A compliance date of December 2015 was provided to address	
		these concerns.	

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
Discussion of OEPA	DMP (11 February 2015)	A meeting was held with the DMP to discuss the points raised	1. A risk assessment has been conducted and is appended to
Response to July 2014		in the November 2014 OEPA correspondence (see above). As	this closure plan.
Closure Plan		a general comment, the DMP advised that it had not	2. Waste dump construction, design and rehabilitation
		recommended for the closure plan to not be approved, but	implementation information is presented in the
		had advised that there were several improvements that should	Implementation section
		be addressed in the next closure update. With respect to each	3. Waste dump data sheets, including low grade stockpiles, are
		of the nine concerns raised:	appended to this closure plan.
		1. Risk assessment: accepted by Rio Tinto with no further	4. DMP consultation has been undertaken and is discussed in
		discussion	this register.
		2. Management controls: DMP indicated that this concern	5. Pastoral activity is no longer discussed as a potential final
		related specifically to the absence of specific waste dump	land use.
		rehabilitation design information in the Implementation	6. Rio Tinto has re-evaluated its approach to objectives and
		section of the closure plan, and reliance of adherence to	criteria over the past several years, and the outcomes are
		Landform Design Guidelines without explanation of how these	presented in this closure plan.
		would be specifically applied.	7. Zones of instablity are discussed in the Identification and
		3. Long Term low grade stockpiles: accepted by Rio Tinto	Management of Closure Issues section of this closure plan.
		4. DMP consultation: DMP indicated that it was generally	8. DoW consultation has been undertaken and is discussed in
		comfortable with the level of consultation undertaken by Rio	this register.
		Tinto in relation to closure planning.	9. Rio Tinto has re-evaluated its approach to objectives and
		5. Final land use: accepted by Rio Tinto	criteria over the past several years, and the outcomes are
		6. Closure objectives: DMP indicated that this concern related	presented in this closure plan.
		specifically to a failure to clearly articulate in the closure	
		objectives that the site would meet the Department's	
		minimum expectation of safe, stable and non-polluting	
		landforms.	
		7. Zones of instability: accepted by Rio Tinto. The DMP	
		inidicated that it may accept waste dumps within the zone of	
		instability of a pit, but that this would need to be approved on	
		a case by case basis.	
		8. Consultation with the DoW: accepted by Rio Tinto.	
		9. Completion criteria: accepted by Rio Tinto.	

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
Consultation Stage DMP Environment Division Inspection	Stakeholder & Date DMP (14 July 2015)	<ul> <li>Summary of discussion relevant to closure</li> <li>DMP Environment Division undertook an inspection of the West Angelas mine on 14 July 2015. The following points relevant to closure were raised in the corresponding inspection report:</li> <li>1. The backfilled portion of open cut pits such as Deposit A requires progressive rehabilitation. This is to enable the land to become a self sustaining ecosystem therefore meeting closure objectives of safe stable and non-polluting landform.</li> <li>2. The establishment of abandonment and pit safety bunds is recommended to be installed in early stages of pit development as it will be easier to implement in regards to gaining access.</li> <li>3. Rehabilitation of south west dump bottom lift trial was progressing well, and it appears that species diversity and cover is abundant. Rehabilitation of East Dump also appeared to be progressing well with abundant native plant diversity.</li> </ul>	Response The EMP no longer contains a section on Closure and Rehabilitation, as this is now addressed by this document.

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
Consultation Stage Pre-referral consultation regarding the Deposit CDG proposal	Stakeholder & Date DoW (15 November 2016)	<ul> <li>Summary of discussion relevant to closure</li> <li>Various stakeholders were consulted prior to submission of environmental referral. Whilst a number of issues were raised, the only issues with direct relevance to closure were raised by the DoW.</li> <li>1. Concern was raised about the ability to restore the natural groundwater regime at closure, particularly with removal of the delorite dwe structure through Deposit C</li> </ul>	<b>Response</b> 1. The water level at Deposit C3 is higher (~636mRL) than that observed at Deposit C2 to the west (~624mRL). The dyke is assumed to form a groundwater divide between Deposits C2 and C3 and its removal is expected to result in level equilibrating, with a permanent reduction at C3. Groundwater level reductions may extend for an undetermined distance to the past. The impact of this is not expected to be similiated
		<ul><li>2. The DoW sought to understand the closure strategy for the proposed diversion of Turee Creek East tributary.</li></ul>	<ul> <li>and no attempt to restore levels will be made. The proposal is</li> <li>based on the assumption that there may be a long term</li> <li>reduction in groundwater levels of up to 8m at a location</li> <li>within Karijini National Park which hosts a potential</li> <li>groundwater dependent ecosystem. Studies suggest this will</li> <li>not be environmentally significant.</li> <li>2. Specific designs are yet to be finalised, but the diversion is</li> <li>intended to be permanent.</li> </ul>

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
Comments received for	EPA Services (February	Comments received on West Angelas Deposit C and D	1. The closure plan currently aligns with the ERD document
Deposit C and D	2018)	Environmental Review Document from combined regulator	and environmental impact assessment that impacts from the
Environment Review		agencies; EPA services, DWER and DBCA.	proposal are of low significance. The closure plan makes
Document		1. Concerns raised that West Angelas MCP does not	reference to closure planning process and regular review of
		adequately address the manage of impacts on biodiversity,	risks. If risk presents through the review process then closure
		GDE's or impacts to groundwater resources prior to	strategies will be developed and presented in subsequent
		contamination.	closure plan update.
		2. Update to Figure 27 closure domain map	2. Updated in revised plan
		3. Update to Figure 15 surface hydrology map	3. Updated in revised plan
		4. Cracking Clay PEC translocation trial is not required or	4. Noted and reference removed
		encouraged.	5. Indicative completion criteria have been developed in
		5. SMART completion criteria should be developed and	response to feedback to Feb 2015 plan that was accepted in
		included in the closure plan.	June 2016 and to align with other RTIO sites. These will
		6. Further detailed is required for current and proposed	become more specific as site moves towards closure based on
		rehabilitation monitoring program.	improved information arising from monitoring, research and
		7. Prepare a Closure Plan consistent with DMP and EPA	trials, and reflecting evolving stakeholder expectations for
		Guidelines for Preparing Mine Closure Plans (2015), which	closure outcomes.
		includes a Closure Objective to ensure that vegetation on	6. Further information included in revised plan.
		rehabilitated land is self-sustaining and compatible with the	7. The Plan contains an objective relating to rehabilitation on
		final land use and also includes methodologies and criteria to	vegetated land being self-sustaining and compatible with the
		ensure progressive rehabilitation of habitat for conservation	final land use with relevant criteria relating to the
		significant species.	establishment of habitat as described in Table 7. The
			proponent is committed to progressive rehabilitation as
			described in Section 13 of the Plan.

# Rio Tinto West Angelas closure knowledge database

The closure knowledge database is a summary of the technical reports that directly or indirectly contribute to the development of the closure plan. These documents do not form part of the report and are for indicative purposes only.

The knowledge and understanding of closure issues and management strategies evolve and improve over time, coincident with the development of the mining operation. As a result, some components of some reports and studies may be superseded by new research or studies. While the closure plan addresses the current state of understanding and strategy for closure, the closure knowledge database captures the historical development of closure knowledge, and demonstrates how experience and knowledge developed at other Rio Tinto sites has been considered during the development of the closure plan and across the life of the operation. Accordingly, some information presented in the closure knowledge database may be obsolete.

Technical reports supporting the closure of the operation will be presented as part of the last plan produced prior to the implementation of closure (also known as the Decommissioning Plan).

#### **Geochemical characterisation**

#### CONFIDENTIAL

Acid Generating Potential, Selected Core Samples Mt Newman Member BIF, West Angeles Deposit A Open Pit	1988
A preliminary assessment of the potential for the generation of acid drainage was undertaken on banded iron formation samples from West Angeles Deposit A open pit.	Internal reference: RTIO-PDE-0030854
Only one of the five samples was determine to have acid generating potential. Three of the samples tested contained reactive carbonates.	
Review of Waste Rock Geochemistry a) General Overview of Acid Base Accounting	2006
This report contains a general overview of acid base accounting and a summary of the geochemical test work that has been previously completed for various sites and lithologies.	Internal reference: RTIO-PDE-0021130
There are large discrepancies in the total sulfur concentration measured using XRF and LECO machines. The XRF machine underestimates the sulfur concentration at values greater than 2%. Materials with total sulfur concentrations less than 0.1% can contain low capacity PAF material, however, it is considered only to be low additional acid and metalliferous risk if the boundary for inert material and potentially acid forming material is shifted from 0.02%S to 0.1%S. A paste pH result of less than 7 should be sent to the black shale dump and a paste pH result of greater than 7 can be sent to an inert material waste dump.	

# Geochemical Characterisation of Paraburdoo Lens 2, Tom Price North Deposit Dales Gorge and West Angelas Samples

A geochemical assessment was undertaken on samples from Paraburdoo, Dales Gorge and West Angelas to determine acid generating potential, oxidation rates and leachable contaminants.

Seven of eight West Angelas (Deposit A) samples studied were classified as potentially acid forming. In samples of banded iron formation and/or shale lithologies from the three mine sites C, S, As, Au, Bi, Mo, Sb, Se, Sn were enriched. Only Mo and Se were readily leachable.

## Mineralogical Analysis of Potentially Acid Forming Materials

Quantitative mineralogy (QEM-Scan) for samples of rock collected from Tom Price, Channar, West Angelas, Brockman, Paraburdoo, East Extension, Western Turner Syncline and Hope Downs 1 North was undertaken. Comparisons were made between two methodologies use to characterise potentially acid forming materials; acid base accounting and mineralogical analysis.

All samples contained elevated total sulfur concentrations and the lithologies were either shale, banded iron formation or dolomite. Pyrite was the dominant mineral contributing to acidity and the dominant sulfate secondary mineralisation consisted of alunite and jarosite.

## Determination of ARD potential of Rio Tinto Iron Ore (WA) Waste Rock Samples

This report investigates the use of mineralogy to predict acid and metalliferous drainage potential. Analysis of numerous rocks was undertaken using QEM-SCAN.

Areas of waste rock which have underdone oxidation can be identified where sulfur-bearing minerals vary between samples in the form of pyrite, alunite and jarosite. The variability of gangue mineral phases suggest that some areas of composite waste rock pile may provide some neutralising potential while other areas will have no neutralising potential. Variable textural and mineralogical controls on sulfide mineral occurrence result in decreased accessibility of pyrite to oxidising fluids.

#### 2008

Internal reference: RTIO-PDE-0034616

#### 2008

Internal reference: RTIO-PDE-0053725

#### 2008

Internal reference: RTIO-PDE-0051613

## West Angelas ARD and Geochemical Risk Assessment

Risk associated with acid rock drainage in the current, possible and future deposits at the West Angelas project area have been investigated.

Deposit C and G pose low-nil risk of acid and metalliferous drainage. Deposit A, E and F poses a low risk. Deposit D a moderate to low risk and Deposit B a moderate risk. High risks have been classified for WA6 Area (southern West Angelas project area) WA7 Area (northwest of West Angelas project area), WA8 Area (west of Deposit A), WA9 Area (west of Deposit A) and Angelo River.

## Contaminant Leaching from Non-Sulfidic Waste Material

The available leach extract data and information pertaining to the distribution of metals and metalloids in non sulfur materials at neutral pH was reviewed. Based on this review conceptual models for controls on their leaching and mobility were developed.

The review found that contaminant leaching from non-sulfidic materials was generally very limited. Usually the pH in leach tests was near-neutral (pH 6 to 8), and dissolved contaminant concentration were at or below detection limits. It is believed that a primary leachable contaminant source is the oxidation of sulfide minerals. Release from oxidising sulfides leads to release of soluble reaction products. Under neutral pH conditions, there is the potential for release of these contaminants when those products dissolve.

# Environmental Status of Selenium (Se) in the Pilbara Region of Western Australia – Potential Risk from Iron Ore Mining

This report includes information about Selenium geochemistry, distribution in the environment, occurrence in rocks in the Pilbara and potential risks to the environment.

The Selenium (Se) content of shales containing significant pyrite should be recorded as part of the overall risk assessment for acid and metalliferous mine drainage. However, it should also be noted Se solubility is far less constrained by pH than in the case of metals and near neutral drainage may contain significant Se concentrations in solution. It would be most useful to study the Selenium budget of the wetlands in the Pilbara as, apart from the chance poisoning of livestock from the consumption of plants that have taken up high concentrations of Selenium, impacts are most likely to be felt in wetlands receiving mine site drainage.

## Contaminant Leaching from Low-Sulphur Waste Minerals (Summary)

RTIO's Geochemical Database was reviewed and based upon this data, conceptual models for controls on the leaching and mobility of a range of metals and metalloids were developed. This summary also describes potential controls on the amount of dissolved element that may be released. This is a summary of a comprehensive report RTIO-PDE-0100104.

For most contaminants, dissolved concentrations at circum neutral pH (pH 6 to 8) were very low, typically at or below detection limit. Geochemical modelling indicates that water-rock interactions are controlled by equilibrium, for salt, carbonates and sulphates this equilibrium is often source term limited whilst hydroxyl-sulphates and hydroxides are solubility controlled. Results also indicate that sorption plays an important role in solute concentration; weak (but detectable) sorption occurred for selenium and zinc whilst the strongest sorption was evident for cobalt. The review suggested that storage waste facilities containing low-sulfur materials pose a low level of environmental risk however, there is a small risk of increased in mobility of some contaminants if acidic conditions arise. Acidic conditions can sometimes arise from the interactions between iron and aluminium hydroxyl-sulphates and hydroxides.

## West Angelas Deposit B AMD Risk Ranking July 2012

Memo regarding review and update of the 2008 West Angelas deposit B AMD risk assessment and ranking.

The risk assessment (Terrusi 2008) indicated that the rocks from Deposit B were enriched in As and Fe and elevated in Sn for most strand-tag groups, with Cr, Mn and Pb elevated in some others. It is unlikely that these elements will mobilise under neutral conditions as demonstrated by Brown (2012). The overall AMD hazard score for West Angelas Deposit B is Moderate. One of the largest contributors to the Moderate risk rating is around surface water management. Currently there is a significant creek line that is located where the proposed Deposit B pit is located. Diversions are recommended to control the surface water from entering the pit or mobilising salts from the pit wall that would reduce the chance of contaminants from polluting the surrounding environment. If the diversion is implemented the AMD risk rating for the deposit would become low.

Internal reference: RTIO-PDE-0052917

#### 2011

2010

Internal reference: RTIO-HSE-0145041

#### 2011

Internal reference: RTIO-PDE-0103857

#### 2011

Internal reference: RTIO-PDE-0090689

#### 2012

Internal reference:

## Geochemical Assessment of Samples from West Angelas Deposits, B, D and A West

Report summarising geochemical testing of samples from West Angelas deposits B, D and A west for the purpose of; determining acid forming characteristics of waste rock, provide a preliminary assessment of the likelihood of occurrence of potentially acid forming rock types, assess the reactivity of any sulphide mineralisation to provide estimates of geochemical behaviour and lag times for acidification, identify element enrichments that could be environmentally significant and assess mobilisation of elements, provide recommendation for kinetic testing.

Testing has been conducted on seven different waste rock types from two deposits of the West Angelas Mine and indicates that 79% of the samples have a low total S content and 71% have a low acid neutralising capacity (ANC). About two thirds of the samples (66%) were NAPP negative and one third (34%) were NAPP positive.Sulphur speciation testing indicated that for all but one of the samples selected, the majority of the sulphur occurs in non-acid generating forms. Results suggested that the total S content of samples from West Angela Mine cannot be used reliably as criteria for identifying PAF material types at the West Angela Mine. Materials represented by the samples may have elevated concentrations of As, Be, Fe, S, TI and V, however, the solubility of most of these elements at circum-neutral pH was low for the samples that were tested. Overall, 92% of the samples are classified as barren or non-acid forming (NAF) and 8% potentially acid forming (PAF or PAF-LC).

#### Geochemical Assessment of Tailings from Yandi, Paraburdoo, Tom Price, Brockman 4 and Mesa J

This report presents the results from geochemical testing and saline solution extraction of tailings samples from Yandi, Paraburdoo, Tom Price, Brockman 4 and Mesa J deposits.

Overall the tailings from these operations are unlikely to generate acid and are not expected to leach significant levels of metals under oxidising or saline conditions.

#### Greater West Angelas AMD Risk Assessment

The acid and metalliferous drainage (AMD) risk assessment for the West Angelas deposits has been updated from an assessment completed in June 2008. This current assessment takes into account total sulfur concentrations within rock types, considering recent drillhole data associated with the greater West Angelas area and individually within the currently available final pit shells. Logging data and the samples location with respect to the water table was used to indicate whether sulfur is in the form of sulfide or sulfate minerals. Geochemical data is also assessed to identify enriched elemental concentrations which may pose an environmental risk. This data, along with site specific baseline information, can be used to generate a conceptual site model to describe mechanisms by which acid and metals/metalloids may mobilise and interact with environmental receptors.

AMD risks for all deposits are low, based on the current pit designs. Although pyrite has been visually identified in drillhole samples, no pyrite samples are located within the current proposed pit shells. The sulfur associated with elevated-sulfur samples are likely to be associated with sulfate minerals including gypsum which will not generate acid, or alunite which has the potential for relavitely low levels of acid release from elevated-sulfate samples. The low solubility of alunite means that only a low flux of acid (and contaminant) release. Fe, As and Sn, as well as Co, Cr, Cu, Mn, Ni, Pb and Zn have been identified as being enriched in West Angelas deposits and should be monitored in groundwater.

#### Oxidation and solute accumulation in dewatered pit wall rocks

Dewatering and removing the water table may result in de-saturation of sulphide-bearing lithologies. This study was undertaken to review how oxygen ingress and consequent sulphide oxidation of Mount McRae Shales could impact water quality when the groundwater table rebounds after mining.

#### Large Scale Column Construction Procedure and Initial Chemistry

Large scale column experiments have been constructed to examine the reactivity of hot and cold black shale material in an operational environment. The memo describes the construction of the columns and the first geochemistry data collected after small rainfall events at Rhodes Ridge.

Initial results suggest that effluent water retains the chemistry of the incident rainfall. Constituents to note in the initial chemistry include nitrate and ammonia detected in the hot black shale effluent. This study provides an important comparison between laboratory characterisation studies and field reactivity of waste rock. Data from the large scale column tests can be applied to reactivity of in pit waste/talus as well as waste rock dumps. It can be used as an intermediate to predict long term reactivity of waste rock.

#### Greater West Angelas Risk Assessment

The West Angelas AMD risk assessment was updated to incorporate proposed Deposits C, D and G and Angelo River

Deposits C, D and G were assessed to have a low AMD risk. The Angelo River deposit was assessed to be a low-moderate AMD risk, based largely on the size of the deposit. <1% of samples in all deposits had sulfur concentrations about 0.3%, and those above this threshold are assumed to result from sulfates.

Geochemical characterisation

Internal reference: RTIO-PDE-0120532

2013

#### 2014

Internal reference: RTIO-PDE-0123030

#### 2014

Internal reference: RTIO-PDE-0120775

#### 2014

Internal reference: RTIO-PDE-0109045

#### 2014

Internal reference: RTIO-PDE-0123894

## 2016

Internal reference: RTIO-PDE-0120775

#### **Physical characterisation**

#### <u>Field rainfall simulator and overland flow study of waste and topsoil erodibility - Nammuldi and</u> <u>West Angelas Mines - Pilbara Iron</u>

This study was carried out to assess the erodibility of dominat wastes and topsoils on Nammuldi and West Angelas mine sites, to provide a basis for the design of stable landforms for rehabilitation. To determine the erodibility of materials, simulated rain and overland flows were applied to experimental plots, and measurements made of runoff and sediment in runoff. Erodibility parameters for the WEPP runoff/erosion model were derived from the data, and the model was run using 100-year climate files.

Several of the West Angelas materials (two wastes, one topsoil) showed a degree of similarity. For those three materials, it appears that - if linear batter slopes are constructed - the maximum landform height likely to be stable is 20 m. If it is essential that waste dumps be constructed to a greater height, then concave profiles and rock armouring could enable a significant increase in landform height. If such options are likely to be requried, forward planning (including sourcing and stockpiling competent rock) would be advisable. The other material studied at West Angelas (low grade fines from the Roche crushing plant) would only give a 10 m high linear batter slope of acceptable stability, and will clearly need to be covered with more erosion-resistant material if batter slopes higher than 10 m are to be rehabilitated.

#### <u>Net solute load response to the installation of infiltration limiting dry cover systems over acid</u> forming waste piles

This work was conducted to verify the central design concept of store-and-release covers over sulfidic above water table waste dumps that is, whether limiting net percolation volume through the cover results in a lesser sulfate and acidity load being realised generated and passing through the dump.

The results from this thesis project confirm that the central aim of store-and-release covers to reduce net percolation volume is a valid measure for reducing the net loading of sulfate and acidity. The mechanism through which decreasing net percolation (applied water volume) results in a lesser sulfate and acidity load was identified, however further work in a site context is needed to assess how this relationship between percolation volume and loading persists in the real-world environment.

#### **Growth Media Characterisation**

# This study was undertaken to interpret material characterisation data from 53 samples and their review their potentials as growth mediums.

53 samples were assessed has been classified as 'suitable' or 'not suitable' for use as a growth medium. This report should be used as a guide to assist in selecting materials that can be considered for use in rehabilitation activities, provide that these other factors are also included as part of the rehabilitation plan. Several materials have properties that were invariably suitable. In some cases, materials have some properties that are suitable and others unsuitable. In others, serval of the properties are problematic. Suitable materials represent those that have base properties that are not likely to impede vegetation. Marginal materials are those that are likely to support vegetation but that have some properties that are likely to support vegetation but that have properties that are likely to significantly impact on vegetation growth either through being saline, prone to dispersion, and having pH values guite different to those typically observed.

#### Groundwater

### West Angelas Deposit D Hydrogeological Conceptual Model Report

This report describes a conceptual hydrogoeological model for West Angelas Deposit D.

The aquifer at Deposit C is principally associated with the mineralised section of the Mount Newman Member of the Marra Mamba Iron Formation as well as the overlying Wittenoom Formation. The groundwater gradient is relatively flat across the area, with the groundwater flow direction to the west. Due to the depth to groundwater, as well as the thickness of clayey detritals, it is expected that rainfall recharge will be low.

#### West Angelas Deposit C Hydrogeological Conceptual Model Report

This report describes a conceptual hydrogoeological model for West Angelas Deposit C.

The aquifer at Deposit C is principally associated with the mineralised section of the Mount Newman Member of the Marra Mamba Iron Formation as well as the overlying Wittenoom Formation. Evidence for a groundwater divide exists in the centre of the site, in an area of a dyke, possibly forming a barrier to groundwater flow. Due to the depth to groundwater, as well as the thickness of clayey detritals, it is expected that rainfall recharge will be low.

Internal reference: RTIO-HSE-0036709

2006

2014

Internal reference: RTIO-PDE-0128431

2016

### Internal reference: RTIO-HSE-0298702

2015

## Internal reference: RTIO-PDE-0135949

## 2015

Internal reference: RTIO-PDE-0135550

#### Water interactions and pit lakes

#### <u>Geochemical and hydrological processes controlling groundwater salinity of a large inland wetland</u> of northwest Australia

Understanding mechanisms of hydrochemical evolution of groundwater under saline and brine wetlands in arid and semiarid regions is necessary to assess how groundwater extraction or injection in large-scale basins may affect the natural interface between saline–fresh aquifers in those systems. This paper investigated the evolution of groundwater of the Fortescue Marsh, a large inland wetland of northwest Australia.

The deep groundwater (>50m depth) of the Fortescue Marsh is highly saline (>100g/L), whilst shallow groundwater (~0–20m depth) and surface water are mainly fresh or brackish. Currently, the marsh is mainly recharged by occasional floodwater. Consequently, salt in the marsh is concentrated by evaporation of rainfall. It was found that groundwater associated with the marsh could be divided into two groups characterised by their stable isotope compositions; i) fresh and brackish groundwater (TDS b10 g L–1;  $\delta$ 180 –8.0 ± 0.9‰) and ii) saline and brine groundwater (TDS N10 g L–1,  $\delta$ 180 varies from +2.5 to -7.2‰). Fresh groundwater was evaporated by<20% compared to rainwater. Brackish water mainly reflects modern recharge whilst saline and brine groundwater reflects mixing between modern rainfall, brackish water and relatively old groundwater.

#### Flora

#### Flora & Vegetation Survey of Orebody A & B West Angela Hill and Rail Route Options March 1998

Report defines premining flora and vegetation communities for West Angelas Deposits A and B as well as the access road and proposed rail alignment options.

There are two vegetation types of conservation significance in the West Angelas Deposit A and B and access road study areas. These consist of Cracking Clays and Mulga stands. Cracking clays found both to the west of Deposit A and south of Deposit B are locally significant as the contain species which are both rare and edaphically restricted. There are two significant stands of Mulga in the West Angelas area. The first of which is west of Deposit A on a broad alluvial fan. This area is of conservation significance not because of its regional restriction as it is found elsewhere but beceause of the condition of the stand as it has had little to no impact from grazing. The Mulga stand north of Deposit B and the mine access road is of high conservation value (vegetation type (6adb231)) due to the unique species assemblage where Acacia aneura var. (green, flat; MET 15, 946) is dominant.

### Flora & Vegetation Survey of Orebody A & B West Angela Hill and Rail Route Options March 1998

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#### Robe River Mining Southern Spur rail route Mulga monitoring programme - December 2004

Results of 2004 Mulga monitoring programme for the Southern Spur of the West Angelas Rail.

The results suggest that there has been no decline in the health of perennial emergent and perennial grasses along the southern spur rail route, with no overall increase in the cover of perennial grasses and health of perennial emergent at the control and experimental sites.

1998

1998

Internal reference: RTIO-HSE-0202800

Internal reference:

RTIO-HSE-0202800

Internal reference: RTIO-HSE-0198428

2013

2004

## Vegetation and Flora Survey of Deposit E and F

Biota Environmental Sciences (Biota) was commissioned to undertake a flora and vegetation survey of Robe River Mining's (Robe's) Deposits E/F study area at West Angelas in May 2004. This report describes the results of this study, and also integrates data previously collected from the area.

Twelve vegetation types were identified within the Deposits E/F study area. The following vegetation types within the study area are considered to have moderate conservation significance: • Mulga vegetation types M1-M5: which was considered to be relatively restricted in the area, and also comprise ecosystems at risk in the form of grove/intergrove and valley floor mulga; • Vegetation types Hi and H3 of stony hills and gorges respectively: these comprised the main mapping units from which the undescribed spinifex species Triodia sp. Mt Ella was recorded. This Priority 3 taxon is known only from the vicinity of West Angelas, and is apparently uncommon and restricted in distribution. It can therefore be surmised that any vegetation type in which this species is a significant component will also be uncommon and restricted. The remainder of the vegetation types are considered to be of low conservation significance, representing units that are likely to be widely distributed and relatively well represented in the Hamersley Range subregion. None of the vegetation types within the Deposits E/F study area are considered to be sufficiently rare or restricted at a subregional level to warrant designating them as being of high conservation significance. No Declared Rare Flora have been recorded within the Deposits E/F study area. Eight Priority flora have been recorded from the Deposits E/F study area. There were also five records of the Priority 2 Acacia effusa from south of the main study area.

## West Angelas Coondewanna Mulga Monitoring 2008-2009

## Results of 2009-2009 Mulga monitoring programme for the Southern Spur of the West Angelas Rail.

The majority of perennial grass test site were moderately to heavily burnt in 2006, and the data from these sites clearly demonstrates that fire is still the dominant influence on the extent of perennial grass cover at these sites, although a partial recovery is now evident. The influence of fire on these sites is so great as to mask any other effects which may or may not be present due to change in surface hydrology. Comparison of the mulga health status 2008 data relative to 2002 indicated only six of the 51 transects tested were significantly different, of which three sites declined and three sites improved. As with the perennial grass data, the equal proportion of declining and improving sites suggests that, at least at a broad scale, the rail infrastructure is not resulting in deterioration in mulga health status.

## UWA West Angelas Mulga Report - February2010

Review of long term mulga vegetation monitoring that has been conducted for Rio Tinto ore iron. The review measured any potential impacts of slatered surface hydrology that maybe attributed to rail infrastructure, provide a combined monitroing data set and re-analyse each data set and combine to provide new insight to whether changes in vegetation condition could be attributed to rail infrastructure for the three long term monitoring site of Yandicogina, Marandoo and Coondewanna flats (West Angelas southern rail spur).

Review, comtination and re-analyse of the three long term data sets found that there were no trends in the combined dataset that indicated that the Central Pilbara Railway has had a negative effect on the density of mulga on either side of the rail line. It was also found that fire is the most significant factor in mulga density and it could not be estiblished if a drainage shadow effect has occured as not soil moisture analyse has been complete upslope or downslope of the rail.

## West Angelas Coondewana Mulga Monitoring 2011

## Results of 2011 Mulga monitoring programme for the Southern Spur of the West Angelas Rail.

No clear trends in changes to total cover of perennial grasses at unburnt or lightly burnt test sites relative to the baseline survey were detected, suggesting that, at least at a broad scale and within this time frame, the rail infrastructure has not resulted in deterioration in the health of these species. Similarly the lack of any clear trend in unburnt or lightly burnt control sites relative to 2001 suggests that seasonal differences between surveys periods have not contributed significantly to the changes in total cover. Data from transects burnt moderately or severely clearly demonstrates that fire remains the major influence on the extent of perennial grass cover. The influence of fire on these transects is likely to mask any other effects which may or may not be present due to change in surface hydrology. There appears to have been a decline in seedling numbers at test sites, and a concurrent increase in shrub numbers, suggesting that some seedlings have grown to the extent that they are now classified as shrubs. The number of trees has increased marginally from the significant decline observed in 2006 post burning, but remains significantly lower that in the baseline survey of 2001. In contrast the cover of perennial grasses at burnt sites is generally now increasing, though still lower then pre-fire levels. Consideration of the location of each transect in the landscape has shown no trend in mulga health status. As with the perennial grass data, an equal proportion of declining and improving sites suggests that, at least at a broad scale, the rail infrastructure is not resulting in deterioration in mulga health status.

#### West Angelas Rehabilitation Record South and East Waste Dumps

Two separate waste dump berms on the West Angelas South waste dump and East waste dump were rehabilitated in 2012.

The waste material on the berm was highly erodible West Angelas shale material, such that slope angles up to 17 degrees were required. The slopes were dressed with 200mm topsoil, deep ripped and seeded.

2006

Internal reference:

#### 2009

Internal reference: RTIO-HSE-0145907

#### 2010

Internal reference:

#### 2012

Internal reference:

## 2012

Internal reference: Rehab close out rep

# Greater West Angelas Vegetation and Flora Assessment, ecologia, April 2013

Rio Tinto (RT) commisioned ecologia Environment (ecologia) to undertake a two phase assessment of the Greater West Angelas Study Area (Deposits C, D, D extension, G, F, H and Mt Ella were surveyed).

Overall the vegetation condition was found to be excellent. 22 vegetation communities were described. One Priority 1 PEC, West Angelas Cracking-Clays, occurs extensively within the Study Area. This community is further defined as open tussock, on derived cracking-clay loam depressions and flowlines. Local vegetation communities considered to be of conservation significance are detailed including vegetation located in; rocky midslopes, gullies, sandy undulating plains and rocky hilltops.

# West Angelas - Rehabilitation Monitoring Report 2013

This report contains the analysis and summary of results from the 2013 West Angelas rehabilitation monitoring program. This report describes the findings from 2013 monitoring of two transects at the West Angelas east waste dump (WD1 T1 and WD1 T2), and two transects at the south waste dump (WD2 T1 and WD2 T2). For comparison, three reference sites were monitored, viz. C3 and C4 (both located on slopes) and C8 (located on a flatter area).

As the rehabilitation was monitored when it was only 9 months old, any conclusions regarding whether it has been successful or not will be preliminary, and further monitoring will be required to determine any likely trends over time. Several erosion gullys were recorded in WD1T2, and these may be related to the generally lower cover values recorded compared to WD1 T1. Apart from these, the site appears stable. It is apparent that, despite the two rehabilitated areas being given apparently similar rehabilitation treatments, the developing vegetation in the four transects is quite variable. It can be concluded that rehabilitation at some sites (particularly WD1 T1 and WD2 T2) has begun to develop well, while that at WD2 T1 has not yet developed as well. The vegetation, fauna habitat and erosion data provide a useful baseline for future comparison.

# West Angelas Rights Reserved Site - Biological Assessment

A biological assessment was conducted of the Rights Reserved Site YINHARR-20 to determine the signficance of vegetation present, and its potential groundwater dependence.

Vegetation at the site was described as low open woodland and is consistent with that of other minor drainage lines within the West Angelas area and more broadly the Hamersley subregion. Groundwater at the site is estimated to be approximately 40-50m below ground level, and would not be accessible to the species present at the site. The vegetation is therefore more likely to be dependent on surface water flows including runoff from the surrounding hills.

# West Angelas Deposit C and D Groundwater Dependent Vegetation Assessment

The objective of this study was to evaluate the potential for a potentially groundwater dependent ecosystem (GDE) in Karijini National Park may be impacted by groundwater drawdown

Modelling suggests that the groundwater table below a potential GDE in Karijini National Park may be lowered by 3-8m as a result of Deposit C and D dewatering, with maximum drawdown soon after closure, but this is considered to be a worst case scenario as the model did not account for natural recharge. The impact assessment conservatively assumed a long-term 8m drawdown and concluded that this would not lead to significant impacts. Whilst some loss of health may occur, vegetation would have time to adapt to groundwater level changes

#### Fauna

# West Aneglas Vertebrate fauna assessment study April 1998

Report documenting the findings of a vertebrate fauna assessment survey completed between June and October 1997. This report identifies vertebrate fauna species found, fauna habitats and their conservation significance in the West Angelas mine area.

Six fauna habitats were identified as being representative of both the landform features and vegetation associations of the mine area; mulga woodland, rocky gullies, cracking clay, creeklines, hilltop and spinifex plain. The ghost Bat Macroderma gigas was recorded in the mine area as well as several other priority and scheduled species were found. Significant habitats have been identified as the Cracking Clay habitat and Mulga woodland.

Internal reference: RTIO-HSE-0185831

## 2013

2013

Internal reference:

### 2015

Internal reference: RTIO-HSE-0289259

### 2017

Internal reference: RTIO-HSE-0310114

#### 1998

Internal reference: RTIO-HSE-0016008

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## West Angelas Stygofauna assessment survey Nov 1998

The report summarises the findings of the preliminary stygofauna survey for the West Angelas mine and Turee Creek B borefield. The aim of the study was to determine if stygofauna are present in the mine and borefield areas, identify key habitat features and assess potential environmental impacts from water abstraction and detail management options. The study was commissioned to support the Part IV approval for West Angelas.

Of the 44 bores sampled in the area 6 bores contained stygofauna. Five specimens were collected in mine area and one specimen in the Turee Creek B borefield area. Species have not been identified as little was known at the time of taxonomy of Australian stygofauna. It was determined that most influencing factor for stygofauna habitat is dolerite and to a lesser degree black shale. It is thought that the presence of fractures and weathered zones in these two non-permeable substrates are utilised as habitat in the absence of more suitable habitat. Potential environmental impacts from mine are summarised as arising from mine dewatering and potential groundwater contamination

## West Angelas Minesite - Ghost Bat Monitoring Survey

Report documenting surveys were undertaken of known Ghost Bat roosting sites to determine the distribution and abundance of Ghost Bats within the caves located within the mine area. Caves surveyed were located within Deposit B and F as well as the eastern side of West Angelas Hill. A search for potential bat habitats was also conducted on the southern boundary of Deposit B and in a small gully between Deposit B and G that had not previously been investigated.

Recent activity of Ghost Bats were recorded in three out of five caves. No Ghosts Bats were present in any caves searched. Summary of completed management actions in regards to the Ghost Bat management plan and planned future actions.

#### West Angelas Stygofauna Assessment Survey

A re-survey of stygofauna in the Turee Creek borefields and the Jeerinah Formation, within the West Angelas lease area. A total of 20 bores were investigated for their sampling potential. Of the 20 bores investigated only 12 were successfully sampled.

Stygofauna were found in five bores. Up to five major groups were recognised from a single bore location. Bore WB51 revelased representative Amphipods, Copepods, Syncarids, Tubellarians and possibly Isopods. Bore WB54 contained potentially two species of Amphipod, one Copepod species and one species of Tubellarian worm. Copepods were the most commonly recorded stygofaunal group with 40 individuals collected from WB54 and 225 individuals observed in bore WB51. WB51 also revealed a large number of Tubellarian worms with 35 individuals recorded.

#### West Angelas expansion deposits E & F subterranean fauna survey May 2004

Report summarises findings of targeted stygofauna survey for E and F deposits of the West Angelas mining operation.

A review of the geological units present in the valley system containing these deposits suggests that the area is not overly prospective for stygofauna. This is largely because the unit with greatest potential to provide habitat for stygofauna of those present, the superficial alluvials, is situated above the water table. There are also no significant calcrete systems present, which constitute core habitat for stygofauna in other parts of the Pilbara (Humphreys 1999). The deeper geological units that are saturated do not generally support stygal communities in most situations.

### Fauna habitats and fauna assembalges of deposit E and F at West Angelas June 2005

Robe River Iron Associates commissioned Biota Environmental Sciences to conduct a fauna survey of their Deposit E/F study area, adjacent to the existing operations at West Angelas. The survey was conducted over a 9-day period between the 4/5/2004 and 12/5/2004.

Four primary habitats were identified within the project area: broad colluvial valleys, lower stony footslopes, stony hilltops, incised gullies and creeks. One fauna habitat is considered to have moderate conservation significance within the study area, based on the vegetation types. Broad colluvial valleys dominated by Acacia aneura (Mulga vegetation types M1-M5) comprise ecosystems at risk in the form of grove/intergrove and valley floor mulga. Two priority listed species were identified and one short range endemic (trapdoor spiders).

### Greater West Angelas Terrestrial Fauna Assessment, ecologia, January 2014

This report details a baseline fauna survey of the Greater West Angelas study area deposits C, D, D extention, G, F, H and Mt Ella.

Six mammal species (including Pilbara leaf nose bat), 12 bird species and three reptile species are listed as conservation significant. The literature review also identified 32 SRE species that have been previously recorded in the region surrounding the study area. A total of nine broad-scale habitat types have been identified within the study area; 'footslope or plain', 'hilltop, hillslope, ridge or cliff', 'mixed Acacia woodland', 'mesa top', 'cracking clay', 'major gorge and gully', 'major drainage', 'mulga woodland' and 'cleared area'. No habitats recorded were regarded as rare or unique to the study area.

Internal reference: RTIO-HSE-0016004

#### 2001

1998

Internal reference: RTIO-HSE-0014000

#### 2002

Internal reference: RTIO-HSE-0016003

#### 2004

Internal reference: RTIO-HSE-0015937

#### 2005

Internal reference: RTIO-HSE-018209

#### 2014

Internal reference: RTIO-HSE-0215896

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Friday, 16 June 2017
### **Biodiversity improvement studies**

### Evaluation of mine waste materials as alternative rehabilitation growth medium

This study reviewed the physical and chemical properties of soil, tailing and mineral waste from select Pilbara mining operations, to identify waste material and material combinations for use as a topsoil substitute or supplement.

The study showed plant-available nutrients held within the waste materials, although variable, was characteristically low and comparable to natural soils in the region. The majority of the waste materials had macro and micro nutrient concentrations within the range or above the levels measured in benchmark Pilbara topsoil and rehabilitated soils. The pH and phosphorus buffering index of most waste materials were also comparable to that of the benchmark topsoil materials. However, some of the waste types and tailings may need to be mixed with rocky material due to poor physical / erodibility characteristics.

### Genetic diversity in Eucalyptus leucophloia across the Pilbara: Provenance zone implications

This study was undertaken to define the provenance seed collection zones for a common species of the Pilbara, Eucalyptus leucophloia (Snappy Gum). This report details information on genetic analysis conducted on E. leucophloia. Collections of E. leucophloia were made from 20 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in E. leucophloia was high and was typical of that found in other eucalypt species with wide spread distributions. Across the species the level of population differentiation was low and the majority of the diversity was maintained within populations with only 6% of variation partitioned between populations. Genetic variation in E. leucophloia showed little structure across the Pilbara with no clustering of populations based on any geographical proximity or in association with obvious topographical, physiogeographical or geological features such as the Hamersley or Chichester Ranges. Populations towards the edges of the species distribution within the Pilbara showed greater levels of differentiation from populations within the species main range. The high levels of genetic diversity and low levels of differentiation within E. leucophloia implies that seed resources for rehabilitation can be selected from a wide range within the Pilbara.

### Genetic diversity in Acacia ancistrocarpa across the Pilbara: Provenance zone implications

This study was undertaken to define the provenance seed collection zones for Acacia ancistrocarpa (Fitzroy Wattle). This report details information on genetic analysis conducted on Acacia ancistrocarpa. Collections were made from 24 populations across the Pilbara bioregion and genetic analysis was conducted on 16 populations using microsatellite markers.

Genetic diversity in A. ancistrocarpa was high but lower than that in E. leucophloia, another widespread species in the Pilbara. Across the species Pilbara range the level of population differentiation was low and the majority of the diversity was maintained within populations with only 3% of variation partitioned between populations. Genetic variation in A. ancistrocarpa showed little structure across the Pilbara with no clustering of populations based on geographical proximity or in association with obvious topographical, physiogeographical or geological features. Populations towards the edges of the species distribution within the Pilbara showed greater levels of differentiation from populations within the species main range. The high levels of genetic diversity and low levels of differentiation within A. ancistrocarpa implies that seed resources for land rehabilitation and mine-site revegetation programs can be selected from a wide range within the Pilbara

## Root hydraulic conductance and aquaporin abundance respond rapidly to partial root-zone drying events in a riparian Melaleuca species

This study examined partial root zone drying (PRD) responses of Melaleuca argentea.

The results demonstrate that PRD can induce rapid changes in root hydraulic conductance and aquaporin expression in roots, which may play a role in short-term water uptake adjustments, particularly in species adapted to heterogeneous water availability.

### Baseline Terrestrial Fauna Assessment of Pilbara Rehabilitation Areas

In 2011 a fauna survey was conducted within established rehabilitation areas at Brockman 2 and Tom Price mine sites, with the aim of identifying whether fauna is recolonising rehabilitation sites in assemblages comparable to reference sites.

The study found that at least 85 species of native vertebrate fauna, as well as representatives from each of six major groups of invertebrate fauna, are using rehabilitation areas at Brockman 2 and Tom Price, with species compositions that were broadly similar to reference sites. Ant collections were typical of the Pilbara bioregion, with an absence of invasive ant species. The study found greater data correlation between monitoring sites at a particular mine site (Tom Price or Brockman 2) than between rehabilitation and reference sites, indicating the importance of selecting local reference sites. The study concluded that the best candidates for bio-indicators are ants and reptiles.

Internal reference: RTIO-HSE-0109961

#### 2011

Internal reference: RTIO-HSE-0108843

### 2011

Internal reference: RTIO-HSE-0119260

### 2011

Internal reference: RTIO-HSE-0252171

### 2012

Internal reference: RTIO-HSE-0134168

### 2010

### Genetic diversity in Aluta quadrata:Implication for management and provenance zone

This study was undertaken to define the provenance seed collection zones for Aluta quadrata. This report details information on genetic analysis conducted on Aluta quadrata. Collections were made from 8 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in A. quadrata was moderate and lower than in the other two more widespread Pilbara species, E. leucophloia and A. ancistrocarpa. The findings suggest that its populations may have fluctuated significantly in size over time with genetic drift and possibly inbreeding resulting in a reduction in genetic variability, particularly in rare alleles. Despite the narrow geographic range, the level of population differentiation in A.quadrata was relatively high with 25% of the genetic variation maintained between populations and 19% due to differences between the three different locations. This significant genetic structure indicates that A. quadrata consists of three conservation or management units, Western Ranges, Pirraburdoo and Howie's Hole.

### Genetic diversity in Acacia atkinsiana across the Pilbara: Provenance zone implications

This study was undertaken to define the provenance seed collection zones for Acacia atkinsiana (Atkins wattle). This report details information on genetic analysis conducted on Aluta quadrata. Collections were made from 16 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in A. atkinsiana was low and lower than that observed in its congener Acacia ancistrocarpa, a widespread species across northern Australia. The level of population differentiation was high and 30% of the diversity was partitioned between populations across the range of A. atkinsiana. Genetic variation in A. atkinsiana showed some structure across the Pilbara with clustering of populations in the western part of the distribution and from the Hamersley Range, along with other populations that were divergent from these groups. The low levels of genetic diversity and high levels of differentiation within A. atkinsiana implies that seed for land rehabilitation and mine-site revegetation programs should be restricted to specific zones. For rehabilitation of sites within the Hamersley Range we recommend seed collections be restricted to that region. Similarly, for rehabilitation in the part of the distribution west of Pannawonica, seed collections should be restricted to that area.

### Rehabilitation Quality Metric (RQM) Project

Western Australia has no formal process to measure habitat quality and as such RTIO has needed to design its own customised metrics. Vegetation condition scoring has previously been developed by RTIO through a Biodiversity Net Positive Impact Assessment, but a more precise metric was needed. The Rehabilitation Quality Metric (RQM) project was developed to provide a repeatable method to assess rehabilitation quality against pre-determined reference sites, on a site by site basis, to predict rehabilitation ecosystem quality at the time of relinquishment.

The RQM methodology employs seventeen parameters to characterise the landscape, including vegetation, fauna habitat, fauna presence, erosion, and ecosystem function. Parameters are tailored to be an applicable measure for both rehabilitation and native vegetation (reference sites). Parameters are scored, based on measured or observed characteristics, with a value between 0 and 1, with 1 being functional (terrestrial ecosystem is functioning for the maintenance of biodiversity values at a local or property scale) and 0 being dysfunctional (terrestrial ecosystem is failing; indicators of ecosystem function have scored below acceptable levels). Both rehabilitation areas and reference sites are scored. Scores are subsequently determined for the entire mine lease, based on the condition of the land before mining (extrapolated from the reference sites, area weighted) and the likely post-mining conditions (extrapolated from the rehabilitation areas and expected closure domain distribution, area weighted, ie pits with no rehabilitation score 0). The difference between the pre-mining and post-mining scores represents the residual impact of mining.

### Propagation of Pilbara spinifex (Triodia sp.)

Triodia has often been observed to have very poor establishment from broadcast seed. This project investigated alternatives to growing Triodia (spinifex) from seed, focussing on ways to propagate seedlings from wild harvested material.

The project found the most successful propagating material was stolons. Greatest propagation success was achieved when Triodia were collected when semi to fully dormant (mid Winter-Spring). The 'Moist Root Induction Method' recommended by previous researchers was less successful than the standard propagation techniques employed in this project. Success varied notably between populations. Consequently, any future collections of propagating material should target multiple populations to maximise potential for success.

Internal reference: RTIO-HSE-0156732

### 2012

2012

Internal reference: RTIO-HSE-0187256

### 2012

Internal reference: RTIO-HSE-0164020

### 2012

### Pilbara Seed Science Project, Part 2 Final Report Jan 2012

Undertaken between 2009-2012, this seed research investigated germination, biology, dormancy classification and treatments for dormancy alleviation for a range of species from the Pilbara.

The Acacia atkinsiana, Indigofera monophylla and Sida echinocarpa seed lots have physical dormancy. Heat treatments and mechanical scarification improved germination on dormant seeds, however, heat treatments killed non-dormant seeds. The treatments used for *Goodenia stobbsiana* seeds failed to overcome dormancy, suggesting deep physiological dormancy. The *Hakea lorea/ chordophylla* seed lots were found to be non-dormant, with very high germination results in the controls. As such, they will not require any pre-treatments prior to direct seeding. The florets surrounding the *Triodia pungens* and *T. wiseana* seeds were found to restrict germination, however, many of the freshly extracted seeds out of the florets were found to be physiologically dormant. Treatments for dormancy include mechanical scarifier to rupture seed coat, hot water (noting potential damage to immature or non-dormant seeds) and increases to germination through wet / dry cycling and / or temperature cycling.

# Morphological variation in the western rainbowfish (Melanotaenia australis) among habitats of the Pilbara region of northwest Australia.

The aim of this honours thesis was to determine and quantify the extent of morphological variation present in *M*. australis and relate this to environmental variables, which will provide the first step to understanding how the species copes with environmental change.

This results of this thesis found that there was limited evidence that fish morphology correlated with environmental variables

### Patterns of water use by the riparian tree Melaleuca argentea in semi-arid northwest Australia

This thesis examines the water use physiology of the riparian tree Melaleuca argentea, and the ways in which this species may respond to anthropogenic disturbances to hydrologic processes.

M. argentea displays highly plastic root-level responses to heterogeneous water availability and to waterlogging, facilitating high rates of water use and growth in the riparian wetland habitats of the Pilbara. Mature M.argentea trees appear to tolerate groundwater drawdown of at least several metres, most likely by employing the same plastic root strategies to access deeper water. M.argentea can also withstand short periods of severe drought, by adopting a 'waiting' strategy of ceasing growth and shedding leaves to avoid moisture loss, a state from which they can then recover. M. argentea populations are unlikely to thrive under large and prolonged reductions in water availability.

### Priority Species Seed Quality and Germination Final Report

This study investigated the quality and germination biology of a range of priority and keystone (Triodia) plant species from the Pilbara.

Eremophila magnifica subsp. Magnifica has physical & physiological dormancy. Propagation methods other than seed may be more successful. Geijera salicifolia and Olearia mucronata has physiological dormancy. Temperature cycling may be required to stimulate germination. Indigofera ixiocarpa and Indigofera sp. Bungaroo Creek has physical dormancy or is non-dormant. Mechanical scarification may be required. Ptilotus subspinescens is non-dormant and will germinate easily without removal from the perianth sheath. However, seed is likely to lose viability with a few years. Sida echinocarpa and Sida sp. Barlee Range has physical dormancy. Seeds should be removed from the mericarp and then scarified in order to germinate. Triodia pungens has T. wiseana non-deeep or deep physiological dormancy. Germination of de-husked seeds can be improved by applying gibberellic acid or 1% smoke water and wet/dry cycling.

### Early physiological flood-tolerance and extensive morphological changes are followed by slow postflooding root recovery in the dryland tree Eucalyptus camaldulensis subsp. Refulgens

This study investigated physiological and morphological response to flooding and recovery in Eucalyptus camaldulensis subsp. Refulgens, a riparian tree species from a dryland region prone to intense episodic flood events.

E. camaldulensis subsp. Refulgens underwent considerable morphological changes during flooding, including extensive adventitious root production, increased root porosity and stem hypertrophy. Physiologically, net photosynthesis and stomatal conductance were maintained for at least 2 weeks of flooding before declining gradually. Despite moderate flood-tolerance during flooding and presumably high environmental selection pressure, recovery of reduced root mass after flooding was poor.

### 2013

2013

Internal reference: RTIO-HSE-0252169

Internal reference:

RTIO-HSE-0249538

2013

### 2013

Internal reference: RTIO-HSE-0207487

### 2014

### CONFIDENTIAL

### Priority Species Project Progress Report 2013

The Priority Species Project, initiated in 2012, aims to improve knowledge of priority plant species and develop methods to successfully germinate and establish priority species, to enable priority plant species to be integrated into Rio Tinto rehabilitation programmes. This work is being undertaken in conjunction with the Department of Parks and Wildlife.

13 plant species were selected as being potentially suitable for establishment in rehabilitation: Eremophila magnifica subsp. magnifica, Indigofera sp. Bungaroo Creek, Indigofera sp. gilesii, Acacia bromilowiana, Sida sp. Barlee Range, Ptilotus subspinescens, Ptilotus mollis, Acacia subtiliformis, Isotropis parviflora, Grevillea sp. Turee, Hibiscus sp. Canga, Themeda sp. Hamersley Station, and Aluta quadrata. Indigofera sp. Bungaroo Creek and Ptilotus subspinescens were found to readily germinate in laboratory conditions, and a field trial was established at Brockman 4 late in 2013.

### Regional Variation in Metal Concentrations of Pilbara Fish in Relation to Concentrations in Water and Sediments

This study aimed to characterise and document natural, background metal concentrations in freshwater fishes from different locations across the Pilbara in order to understand how local geology may affect baseline metal levels in fish tissues and surface waters. Metal concentrations were analysed from water, sediment and muscle and liver tissues from fish collected from up to 13 sites as yet unimpacted by mining across the Pilbara during October (dry season) of 2012.

Levels of dissolved metals from water samples were generally low. However, some elevated concentrations of Boron, Copper and Zinc were recorded. Concentrations of heavy metals in sediments were variable across the Pilbara. Generally, sediment concentrations were well below the Interim Sediment Quality Guidelines (ISQG). However, metal concentrations in excess of ISQG TVs were recorded for Chromium and Copper at some sites. There was no relationship between metal concentrations in sediment and those in water. Metal concentrations in fish tissue (muscle and liver) varied between species with some significantly higher in some particular species. The study concluded that variation in metal concentrations in water, sediment and fish across pools in the Pilbara was likely to be mainly dictated by the local geological setting in which the pool occurs.

## Progress Report 2014, Ecological responses of native fishes to dynamic water flows in northwest arid Australia

This three year Australian Research Council linkage Project commenced in 2013 and aims to increase understanding of the effects of altered stream flows on the Pilbara freshwater aquatic environment. Project aims: 1. Quantifying fish biodiversity and population structure in relation to hydrological and environmental parameters to identify thresholds of ecological concern for water management; 2. Determine the fundamental physiological, morphological and behavioural adaptations of fishes to variations in water quality using experimental manipulations; and 3. Examine spatial scales of gene flow to determine if increased flows increase genetic connectivity relative to natural-flow sites.

To date work has focuses on characterisation of baseline physicochemical parameters across aquatic habitats within the Fortescue River catchment (Aim 1), analysis of variation in rainbow fish morphometrics and mechanosensory lateral line systems in response to geographic region and water management regime (Aim 2), and extraction of DNA samples from 17 populations across the Fortescue River catchment (Aim 3). The project will culminate in the development of a predictive model for stream restoration relevant to future closure scenarios for above and below-groundwater mines. Results from an honours thesis indicate that rainbow fish body shape varies according to geographic region but fish from a dewatered site (WW Ck) were more streamlined than other populations from the upper Fortescue catchment. This statement of results has been superseded by the results of the actual thesis report RTIO-HSE-0252169.

### West Angelas Cracking Clay Study

Cracking clay community soil samples were collected prior to clearing for constrution of the Deposit B waste dump. The objective was to better understand system functionality with a view to evaluating whether translocation or recreation of similar habitat might be viable.

Two distinct clay layers were observed across the study area. An upper vertosol (cracking clay) layer was found to overlay a red kandasol (structureless clay) layer. All plant growth was observed in the upper vertosol layer, with no roots penetrating the kandasol layer. Physical and chemical properties of the vertosol were assessed as being conducive to plant growth, and the material is expected to be relatively stable if stockpiled. The study concluded that translocation may be viable, and that only the vertosol layer would need to be stockpiled and replaced. However, the kandasol layer (or an alternative clay liner) may be required to replicate its role in hydrological function.

Internal reference: RTIO-HSE-0207486

#### 2014

2014

Internal reference: RTIO-HSE-0216967

Internal reference: RTIO-HSE-0246021

2014

### 2015

### **Progressive rehabilitation**

### West Angelas Rehabilitation Trial - Landform Design Performance

Two rehabilitation trials were conducted at West Angelas Deposit A South and North dumps in 2012. Their performance was evaluated in this study.

The rehabilitation specifications for both trial sites did not conform to current specifications. However, with the exception of one unstable gully in Deposit A South dump, erosion was generally within target parameters. There are several factors that may have caused the unstable gully. A relaxation of design parameters to 12-15m lift heights (assuming a gradient of 17 degrees) appears to be supported, but further testing is required to confirm that this is appropriate.

### Landform design

### Results of flume investigations of the stability of rock mulches

This study assessed the potential for rock mulches to be stripped from the soil surface by overland flows.

Although 150-300mm diameter BIF was not removed by simulated overland flows, even for 100mm/hr simulated runoff on 55% gradients, considerable scour of the spoil between the rocks was observed, indicating potential for long-term development of rills or gullies if the level of rock cover was less than 100%. Large reductions in sediment concentrations were observed when finer rocks were mixed with BIF. The data indicate that it is crucial for any rock mulch to cover a wide range of particle diameters, including a component of finer rocks. The resulting mixed rock created a framework of large rocks that resist movement by flows, while the smaller rocks reduce erosion being anchored within the larger (framework) rock. For rock mulches with a mixture of rock diameters, 80% cover produced acceptable erosion rates. Sediment loads were slightly higher for 40% cover by rock of mixed diameters, and it was speculated that this may also achieve acceptable erosion rates with the addition of vegetation.

#### Final Landform Design Criteria for Use During Mine Planning

Rio Tinto Iron Ore WA have historically designed closure landforms for waste materials with berms ~10 m, lifts ~20 m and ad hoc alterations to batter gradients where erosion rates have been perceived to be unacceptably high. This report integrates recent advances in characterisation and modelling of materials, climate and erosion processes to provide appropriate final landform batter characteristics for key Pilbara mineral wastes and soils.

Material properties of mineral wastes were assessed and classified for the range of mineral wastes found across Rio Tinto Pilbara sites. Climate sequences were used to model and test potential erosion rates for a range of batter configurations (shapes (linear, concave), heights, gradients, berm capacity) and validated against existing slopes for which material and climate data were available. This information was used to develop a searchable waste dump batter database for all major mineral wastes and soils, intended for use during mine planning design.

### Contamination

#### Impact of Nitrogen from Explosives on Mine Site Water Quality

The likely issues associated with the use of nitrogen based explosives on mineral waste and any leachate water are explored in this report. The amounts of explosives used on site are described, along with nitrogen chemistry and toxicity. Nitrogen concentrations for various mine sites and specific lithologies are presented which includes concentration in rock assays and liquid extracts.

It was concluded that the largest risk of nitrogen contamination is likely to arise from the discharge of surface waters that have been in contact with blasted materials and are discharged off site into creeks or waterways. This becomes a more significant issue if the water is also acidic. Algae (ie cyanobacteria) plumes have been identified in acidic water at Tom Price

#### West Angelas Preliminary Site Investigation Report

The purpose of this preliminary site investigation was to identify areas of potential environmental concern associated with current and historical activities at the site.

Results from the risk ranking analysis show that in terms of overall risk factor, no "high risk" areas were identified at the site. The rail refuelling area, the diesel pipeline, the former landfill and the vehicle wash-down facilities were assessed to be of "moderate high" to "moderate low" risk. No previous environmental investigations have been undertaken at any of the facilities, these areas are potential areas of concern and have yet to be quantified. In all cases visual and/or anecdotal evidence suggested that potential adverse impacts to soil, groundwater or surface water, be it fuel spills, leaks or ongoing run-off/infiltration has historically occurred at these locations. For each of these areas of concern, a soil and groundwater sampling and analysis plan should be developed.

Internal reference: RTIO-HSE-0310927

#### 1998

2017

Internal reference: RTIO-HSE-0109221

### 2012

Internal reference: RTIO-PDE-0159989

#### 2008

Internal reference: RTIO-PDE-0054638

#### 2008

### Control Measures for Potentially Acid Forming Pit Wall Rocks

Desktop study of potential strategies to manage exposed sulfidic materials and find viable options for management was conducted with a focus on the Hope Downs 1 and Tom Price sites.

Chemical treatments have the potential to be effective only in the short-term and only for minor water quality issues. Grouting of the pit walls is expected to have limited applicability, although grout curtains behind the wall may have success (untested). Cover technologies have the greatest potential to be effective over the long term, but would need to be resistant to puncture by underlying rocks, resistant to weathering and UV damage is shotcrete, geomembranes. For long term performance the exposed surface need to be as stable and free of loose material as possible. Treatment effectiveness will also depend on the site conditions, eg chemical less effective at Tom Price.

#### Workshop Summary and Desktop Review: Dewatering and Sulfate Accumulation

This is a summary of a workshop held to determine the risks of dewatering sulphides within the pit wall. The outcomes from this workshop will be used to develop models to estimate the mass of sulfate produced as a consequence of dewatering activities.

There are many processes that contribute to poor pit water quality. Most of these processes are known and accounted for in existing models. However, the science of fluid flow in fractured rock is not well developed and this lack of knowledge restricts the outcomes of studies on pit water quality. There is a general lack of empirical data for estimating parameters used in models, creating a large degree of uncertainty in predictive models. Sensitivity analysis can be used to overcome some of these challenges.

#### Contaminated Site Investigation - Soil and Liquid Waste Dumping Area at West Angeles

This report investigats the recent increase in contaminated material placed in storage ponds and potential for infiltration to occur through soil stockpiles to groundwater.

Results of the sampling concluded that there is minimal risk present at the area where the former contaminated stockpile was located. The remaining hydrocarbon concentrations are compliant with the ecological guidelines, with a few areas of elevated concentrations. Concentrations are expected to degrade over time, further reducing the potential for environmental impacts. A new bunded and graded cell has been created at the land farm. The area is expected to be suitable for rehabilitation.

#### Updated Preliminary Site Investigation and Sampling and Analysis Plan for West Angelas Final

The objectives of the project was to update existing information relating to known or suspected contamination at West Angelas and to subsequently develop a sampling and analysis plan in order to further characterise identified areas of interest.

The review of the Preliminary Site Investigation found that, in general, the existing findings are accurate and have been carried out and presented in a manner consistent with the Department of Environment and Conservation Contaminated Sites Management Series. Additional areas of environmental concern were identified during the review. Areas of further interest presented in the sample and analysis plan are: 1) Mine Area - Rail refuelling area, former landfill, fire training ground, contaminated soils stockpile area, crusher area and the current mine landfill; and 2) Workshop / Administration Area - Light vehicle refuelling area, heavy and light vehicle workshop area, heavy vehicle workshop areas, heavy and light vehicle wash-down facilities, bulk oils store, bulk fuels store, intermediate lube store, emergency power plant, recycling yard and the ammonium nitrate / fuel oil shed.

### <u>Development of a conceptual model: Sulfate accumulation as a consequence of pit dewatering</u> activities, memo

Mine dewatering and the consequent lowering of the water table may result in desaturation of sulfide bearing lithologies. The objective of this work was to develop a conceptual model of the associated processes: where sulphide bearing rock intersects the pit walls, and where the sulphide bearing rock is located behind the pit walls but not directly exposed on the pit wall face.

The conceptual model developed estimates the mass of sulfate produced as a consequence of dewatering activities, considering processes during operations and after operations cease, and using sensitivity analysis where parameter inputs are uncertain. The model output provides the basis for an assessment of potential impacts on water quality for general risk assessment applications. Further work was identified to improve parameterisation of the model, including the collection of additional empirical data for pit wall fracturing, saturation of pit wall fractures and sulfide oxidation rates in talus and on pit walls.

### Ethnographic or archaeological values

## Water and Indigenous People in the Pilbara: A Preliminary Study, CSIRO: Water for a Healthy Country

Water resources are vital to Indigenous identities, beliefs, environmental philosophies and livelihoods. This report provides a broad-scale scoping study of Indigenous relationships to water in the Pilbara and considers the potential impacts of Indigenous water values.

Indigenous belief systems perceive water as an elemental part of the broader cultural landscape, held and managed under customary systems of law. Water sources were derived during the Dreaming and are the most important features in the Pilbara cultural landscape. Interviews raised issues of long term drying, obstruction of water flow, over-extraction, inappropriate discharge from de-watering and access restrictions.

### Internal reference: RTIO-PDE-0079541

#### 2012

Internal reference: RTIO-PDE-0101903

### 2012

Internal reference: RTIO-HSE-0142463

#### 2012

Internal reference: RTIO-HSE-0148156

#### 2012

Internal reference: RTIO-PDE-0101903

### 2011

Internal reference: RTIO-HSE-0218222

### 2010

### **APPENDIX D – CLOSURE RISK ASSESSMENT**

Ref. L=L):	Risk Description Evaluated 21 of 21 risks					Risk Eva	uation ቼ ቼ≩	Ce adament	
Type gory ateg						e ibo	te lite	t Man	
Risk Cate	E Threat Title	Potential causes (Triggers (Indicators)	Existing Controls and Commitments	Site specific overview	Evaluation Rationale (Maximum	-ikel	Safet Dn-si	Com	Detailed Action Descriptions
T A T A 01	Planning and knowledge Contaminated sites	(,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			·····,				
T A 01	<sup>21</sup> Under-estimated general contaminant clean up requirements	Use of chemicals and hydrocarbons during operations     Housekeeping practice and maintenance of work areas and equipment	<ul> <li>Regular maintenance / inspection / audit of work place procedures</li> <li>Spill management kits readily available</li> <li>Contaminated sites register maintained across life of operation</li> <li>Contaminated soils treated at landfarm facility</li> </ul>	<ul> <li>Regular maintenance / inspection / audit of work place procedures</li> <li>Detailed stills investigation to be undertaken prof to dosure</li> <li>Preliminary site investigations have been undertaken - no reportable sites have been identified, but housekeeping issues have been identified from time to time</li> <li>Original landfarm was not constructed to specifications - has now been replaced</li> </ul>	Hydrocarbon contamination identified during pre-closure DSI results in unexpected clean-up costs	P		LI	
T A 01	<sup>12</sup> Under-estimated acid and / or metalliferous drainage management requirements during operations (pre- closure) & decommissioning phase	Potential for acid / akkaline / metalliferous / neutral / saline drainage generation during operation of mime Water management, storage and monitoring practices Water quality prior to return to environment e.g. via infiltration or discharge	Geochemical characterisation of waste material     Mineral Waste Management Work Practice     SCARD management plan     PAF waste stored in cells within waste dumps     Wet season management plans used to control run     off.     Groundwater operating management plan to monitor     groundwater outlivy     Water Discharge Monitoring and Management Plan	Low AMD risk assumed across the site	Unexpected PAF is identified and requires management	R	L		
T A 01	33 Acid and / or metalliferous drainage generation (after closure) creates a contaminated site	Interaction of water and mineral waste could generate acid / alkaline levels that leach metals / salts from the mineral waste or local environment • Presence of temporary or permanent open water bodies, enabling evapoconcentration to occur with creation of alkaline / hypersaline water quality • Ability of metals / salts to move through environment to impact a sensitive receptor, to meet definitions in Contaminated Sites Act 2003	Geochemical characterisation of waste material     SCARD management plan provides specifications for     PAF cover     Waste dump design specifications based on material     erodbility parameters     Pits will be backfilled to AWT	• Low AMD risk assumed across the site • No PAF material present behind pit walls	Metalliferous salts build up in the soil profile at the base of pits	U	М	1	
T A 01	<sup>24</sup> Human health impacts from in situ fibrous material exposures	Hazardous fibres exposed in situ by mining, mined and moved to encapsulated areas or naturally present in solis disturbed by mining / rehabilitation activities     Ercsion of materials containing hazardous fibres post-closure	<ul> <li>Physical materials characterisation, some fibres present in mineral waste materials, surface alluvials and associated with infrastructure installation (cuts through non-mined geology)</li> <li>Fibrous materials management plan enacted</li> </ul>	<ul> <li>Fibrous material has been encountered</li> <li>Fibrous material has been encoupsilated in Deposit A North waste dump</li> <li>Pit wall exposures on WEPN north wall have been covered with backfill material</li> <li>Assume that current procedures may result in some fibrous material being present on pit walls in some areas - additional management may be required</li> </ul>	Fibrous materials are re-exposed post-closure, creating to a public health risk (NB - risk evaluated on the basis of minimal potential for long-term public exposure)	UH			<ol> <li>Evaluate closure landform desgins with respect to managing the potential for exposure/re exposure of fabrous materials, and incorporate design changes where required.</li> </ol>
T A 02	Void management	• Open water bories in Pilhara naturally attract found (feral and native	Void closure management quidance	No normanent nit lakes - currently committing to backfill to pre-mining water table level	A permanent pit lake forms at the		M	- M -	1. Undertake groundwater recovery modeling to determine backfill levels for all site
	<ul> <li>Cance and a mean-ringer matching means in the matching and the means in the means in the eccesystem function.</li> </ul>	Open week codes in Under Inders inducting auto-traduct regulared set in termine species) for food water / refugs, eak access to water required      Ornerntration of natural groundwater or mineral waste derived salts      Invogb evapoconentration in open water bodies      Release of metals from natural geology or mineral waste into water      (infination or groundwate flow)      Water provides opportunity for plant. Aveed growth, good and bad (toxic      algal blooms, noolous weeds)      Oratin plant / animal species bio-accumulate / magnify toxic metals      instability associated with saturated, unconsolidated ground, can be      increased by high trafficability	At this stage, all pits will be cackfilled to a level that prevents formation of a permanent pit lake	<ul> <li>No permitted in a last ordering obtaining to deal mining of permitting values last even Considering amonging this commitment to backfill flue prevent formation of permanent pit lake - this would result in a high incidence of sphemeral water in the base of pits - Nay be an opportunity to hallenge this commitment in the future, but would need to undertake sufficient sudies to support that the outcome is acceptable - for the purposes of this risk assessment, assume that this opportunity und he realised - May have temporarylephemoral pit takes     </li> </ul>	A perminent pit also clinits at use base of a mine void, due to inaccurate groundwater recovery information and/or high surface water flow contribution, and leads to an increase of invasive species. (NB: Risk evaluated on the basis that commitments are amended to only require backfill to a level that prevents permanent pit lakes from forming, and that any lake would be a sink)		W		r. Unertaxe grounumeter recovery modeling to determine deuxin erres for en pris.
T A 02	2 Lake poses public liability and / or health risk	Lake(s) in a location that is easily accessible by the general public e.g. near or visible from a public road Lake(s) is near an existing attraction e.g. area of cultural significance or tourist attraction Access to the lake edge is not via a dedicated, safe path Contaminants well above recreational guidelines Strongy acidic or alkaline lake water, or releases noxious gases Toxic algal blooms and / or noxious weeds Waterborne pests and disease e.g. mosquitos	Void closure management guidance     At this stage, all pits will be backfilled to a level that prevents formation of a permanent pit lake     Abandonment bunding around pits to prevent     inadvertant access	No permanent pit lakes     May have temporary/sphemoral pit lakes, generally shallow water expected     May have temporary/sphemoral pit lakes, generally shallow water expected     "Will be installing abandonment bunds in appropriate and agreed locations     "Will be installing abandonment bunds in appropriate and agreed locations	A temporary/ephemoral pit lake forms at the base of a mine vold, and egress routes have collapsec - people and/or stock that enter the pit are unable to exit. (NB: Risk evaluated on the basis commitments are changed to only require backfill to prevent formation of a permanent pit lake)	U	VL		
T A 02	s Degradation of regional groundwater quality or levels	<ul> <li>Concentration of natural groundwater or mineral waste derived salts through evapoconcentration in open water boddes</li> <li>Croundwater flow through pit lake or mineral waste with connection to regional aquifer</li> <li>Density driven saline groundwater flow from groundwater sink-style pit lakes</li> <li>Downstream groundwater users (people, plants or animals)</li> </ul>	Void closure management guidance     Environmental surveys include regional groundwater dependent ecosystem     Geochemical waste characterisation and column leach tests     Preliminary integrated ground-surface water modelling (with recovery) completed     Management of mineral waste to minimise surface water area exposed to evapotranspiration, to minimise salinity	Pils will be backfilled to level that prevents formation of permanent pit lakes and goundwater recovery levels predicted to be up to 70m lower than pre-mining levels, and may take more than 100 years to stabilize The environmental impact of a permanent reduction in groundwater levels has been assessed to be low. The nearest significant groundater dependent ecosystems are within Karijini National Park where it has been assumed that there could be a permeant reduction of groundwater levels but to to the where it has been assumed to be able to successfully adapt to this scenario. No permanent pit lakes (La. Imited water losses from the system due to evaporation) - Low AND risk. - Assume environmental systems are sufficient to prevent formation of contaminated sites with the potential for groundwater impacts - There may be a permanent reduction in stygofauna habitat, but stygofauna species do not appear to be environmental significant, and there are no local groundwater users. - Local aquifers are minor contributors to the regional system.	Permanent reduction of local groundwater levels leads to a loss of environmental values.	P	LL	1	
T A 02	4 Gestechnical zone of instability compromises closure outcomes	- Influence of erosion, subsidence, seismicity, well slip - Influence of groundwater recovery and surface water flow on stability Creek system neighbouring or within zone of instability, potential stream capture - Ecosystem downstream of void dependent on surface water flows - Poor communication of zone of instability to facilitate identification of important features	<ul> <li>Geotechnical assessments for wall stability and zone drollapse as and of mine design reviews, as required - Pit walls design factor of safety 1.3, geotechnical assessment show zone of collapse for high risk locations (near creeks, infrastructure etc.)</li> <li>Conceptual location for abandonment bunds established</li> </ul>	<ul> <li>This has been raised as a specific issue for the site by the OEPA in its response to the 2014 closure plan, and by the DMP in its 2015 environment inspecifor (waste during located within the zone of instability) 2ones of instability are considered when siting new waste durings, but existing waste durings need to be wirrified as outside the polygon     </li> <li>Deposit A south waste during and Deposit E. South during are located within the zone of instability (as calculated using methodology in DMP guidelines)     </li> <li>Also need to consider the polygon         extra during and Deposit E. South during are located within the zone of instability (as calculated using methodology in DMP guidelines)     </li> <li>Also need to consider the polygon (rock shelter and associated access routes) impacts.     </li> <li>Numerous sites to consider across the site         <ul> <li>Additional Backfill in Deposit. All occur - can be undertaken so as to effectively buttress the wall if required, but further evaluation is needed to determine whether this is required.         </li> </ul></li></ul>	Geotechnical failure of a pit wall causes a waste dump to collapse into a pit void, requiring rehabilitation rework after the active post-closure maintenance period	L	HL	M	I. Develop rehabilitation designs for waste dumps that are currently located within zones of instability (Develop II: A South dump and Deposit E South dump) that ensure these dumps are outside the zone of instability.
T A 03	Closure landforms								

-	Ref.	Risk Description					Risk	Evaluati	ion		tent.	
tk Type (T=T	tegory bc ategory	Evaluated 21 of 21 risks	Potential causes			Evaluation Rationale (Maximum	telihood	alth fety	-site vironment -site	vironment mmunity ıst mpliance	k Managem	
L R	<b>B B A</b> 03 <b>C</b>	The The Usu flandforms (excluding mine void areas) erode and / or collapse	(frigger / Indicators) - Physical material properties considered in design - Drainage and erosion management - Construction of landforms / waste dumps to design requirements - Sensitive receptors identified downstream	Existing Controls and Commitments	Site specific overview Significant proportion of high erodbility material in some waste dumps (detritats, shales) Strategies for managing high erodbility material in some dumps constructed to a flatter angle, selective dumping of some dumps and capping of others. Some of these options will require a higher level of operational control than is typical for waste dumping in the Pibara. Some waste dumps (e.g. Deposit A South dump) have not been constructed to readily facilitate a stable closure design. Multi-disciplinary pit and waste dump design sign-off processes, considers landform design guidelines and provides rehabilitation designs where appropriate Need to consider abandommet bund placemet - needs to account for hydrological regime - Deposit A South dump was not constructed and rehabbed to current design standards, but appears to be performing satisficatority (confirmed during DMF inspection in 2015) with the exception of one unstable guily + A number of site features are within PMF flood extent - this needs to be assessed with respect to impacting landform stability, particularly waste dumps - Abandomment bunds will need to be constructed for perpetuity - need to confirm that sufficient inventory of competent rods its available. - Need to consider access roads	reasonable consequence) Excessive erosion of waste dumps resulting in rehabilitation failure and downstream sediment impacts.	P 11	S E		<u>태양 두 8</u> 1	ER	Dealled Action Descriptions 1. Develop new rehabilitation designs for existing waste dumps (e.g. Deposit A) that may not have not be constructed to readily facilitate stable rehabilitation stopes. 2. Undertake further site specific waste characterisation to better define dump erosion potential.
T	A 03 0	2 Surface treatment on landforms limits vegetation growth	- Availability of top soil stockpile soil / poor stockpile management e.g. soil     washed away     - tow molisture retention i.e. hydrophobic soils development, very rocky     materials     - Chemical properties of materials on waste dump / rehab surface e.g. sait     circulation, alkalinity	<ul> <li>Physical and geochemical materials characterisation complete. Materials inner and general expected to be acceptable growth media.</li> <li>Rehabilitation handbock provides direction on surface treatment options.</li> <li>Annual stockpile reconciliation of top soil and sub soil stockpiles, return of 200mm to create quality surface growth media.</li> <li>Wetland rehabilitation trial established, will provide feedback on general waste erosion performance, will look at value of adding mulch</li> </ul>	Soil and mineral waste is typical of the Pillera, and should be conducive to native plant growth     The currently repetical toppoil deficit should be addressed following expansions     Rehabilitation to date is performing well     Current RTIO practice does not include the use of soil ameliorants to assist plant growth     There are a variety of habitat types within the West Angelas area	Rehabilitation success is compromised by the absence of suitable topsoils atochailes, resulting in a requirement to reseed some areas	U		L		1	
T	A 03 0	3 Vegetation is not self-sustaining	• Vegetation established, but does not re-seed in same abundance • Weed competition • Species selection / insufficient species diversity • Animal interference i.e. feral animals eating new growth • Changes to soil water conditions e.g. salinity, water logging etc	Rehabilitation handbock provides guidance on seed selection for appropriate diversity     Top soil stockpiles provide seed bank Wetland rehabilitation trial established to assist in appropriate species selection for post-closure soil water conditions     approver the divergence of the divergence of the divergence a part of decommissioning activities	Remote location not affected by pastorial activity - should not be significant pressures from stock trampling, however there are a lot of carele present in the Angelo area. There are no pit lakes proposed, which reduces the risk of them migrating to the West Angelas area - Detailed site investigation to be undertaken prof to closure Responses to fire are not fully understood, but indications from sites elsewhere in the Pibara suggest that recovery after fire could be expected as long as the rehabilitation has reached a reasonable level of maturity. Rehabilitation utilises a range of species	Rehabilitation areas do not show signs of recruitment, requiring rework to occur	R		L	-	I	
т	A 03 0	4 Access through area post-closure poses public liability risk	<ul> <li>Post-closure access / land-use requirements, e.g. for stock, people, heritage, environmental monitoring, adjacent mining activities etc.</li> <li>Potential for general public to create their own access if appropriate access not provided.</li> </ul>	Regular review and integration of stakeholder feedback into closure plan updates.	Abandonment bunds to be constructed, but locations not confirmed     May be post-closure access to rock shefters and but caves (monitoring, etc.)     To access requirements yet to be determined, but historically there has been a lot of TO movement     hrough the area. Assume that there will be TO's accessing the site for hunting and ceremonial purposes.     Need to construct safe access routes.	Post-closure access of the mine area leads to a third-party injury or fatality	P	м			Ш	1. Confirm abandonment bund locations
Т	A 04 0	I Environmental outcomes outside of disturbance acts do not align with approved environmental impacts	New (proviously unidentified) environmental sites, not considered in weising environmental impact assessment • Changes to environmental conditions due to cessation of artificial support / Miligation activities, e.g. water supplementation • Change to drainage patterns on closure e.g. removal of temporary diversions, drains etc.	Internal ground disturbance approval request system to preven inaverant disturbance • Baseline biological / accosystem health surveys and wisking monitoring to define poser-Imning status • GIS system includes results from all flora, fauna, vegetation surveys • Operational management plan for discharge includes actions relating to water quality and discharge extent targets, to ensure environmental issues are managed during operations • Significant species management plan implemented during operations • Vegetation management plan implemented during operations to monitor and manage impacts to lo vegetation (riparian, understorey and weeds) • Water Discharge Monitoring and Management plan		A permanent reduction of water table levels in Karajin National Park causes significiant impact to groundwater dependent ecceystems	Ρ		L	-	U	<ol> <li>Develop designs for permanent diversions where required.</li> </ol>
T	A 04 0	2 Adverse impact to flora or fauna with conservation status or wider regional impact to high value environment	Scheduled, listed or declared rare and / or threatened species of flora or fauna present in/adjacent to site Downstream regional area of high value Environmental conditions post-closure differ significantly from pre-mining conditions Post-mining land use differs from pre-mining land use	Internal ground disturbance approval request system to prevent inadvertent disturbance Baseline biological / eccosystem health surveys and existing monitoring to define post-mining status GIS system includes results from all fora, fauna, vegetation surveys Operational management plan for discharge includes actions relating to water quality and discharge extent targets (proximity to Fortescue Marsh), to ensure environmental issues are managed during operations Significant species management plan implemented during operation to minimise impact to select species Vegetation management plan implemented during operations to monitor and manage impacts to vegetation (ripartian, understorey and weeds)	Project footprint is surrounded by PEC cracking day communities     Several priority flora and fauna in the area, but conservation status is not expected to be impacted by mining or closure     Oraching clay translocation trials proposed - if successful, these may enable greater disturbance of     cracking clay translocation trials proposed review of protection to the overall environmental value     Communities appear to be mainly dependent on incident rainfall and cutting overland flows to them may     not be significant	Grading of the landscape around cracking day communities changes surface water flow paths or sedimentation, resulting in impacts to ecceystem health	U		H		ш	<ol> <li>Evaluate the final landform design with respect to the potential for impacts to cracking clay communities</li> <li>2. Undertake trials to evaluate the potential to translocate cracking clay communities that may be disturbed during operations or post-closure.</li> </ol>
T	A 04 0	<sup>3</sup> Heritage site condition / cultural value is degraded as a result of implementing the closure plan	New (previously unidentified) heritage sites, not considered in existing assessment, discussions, agreements or with authority to disturb Ohanges to landforms on dosure have potential to after conditions at downstream sites, e.g. consider drainage, landform fodprint, erosion implications • Cessation of maintenance of / to heritage site	Internal ground disturbance approval request system     GIS system includes results from heritage surveys     Heritage sites within mine area, S18 application etc.     prior to disturbance     Ongoing consultation with Traditional Owners	<ul> <li>Several rights reserved areas are present, including a significant sile at Deposit E that is likely to be impacted during mining. Also sites at Deposit F and D         <ul> <li>OPposit E site currently planned to be protected during operations by retaining a 'pillar' - closure             strategies will need to ensure that this is a permanent solution (e.g. buttressing may be required)             volter sites will also need to be considered, but an to considered to be as significant risk of railure as             Deposit E is to be assigned to avoid disturbance of a significant heritage site.</li> </ul> </li> </ul>	Landscape and ecosystem changes impact cultural heritage values in the area (Threat is evaluated on the values of a rights reserved area, such as at Deposit E, to be impacted throguh poor closure design)	P			Н	IV	<ol> <li>Investigate the potential for cultural heritage values to be impacted post-closure, and evaluate the implications of impacts if they arise</li> <li>2. Develop closure strategies to maintain cultural heritage values (e.g. buttressing of Deposit E pilar to maintain its integrity post-closure)</li> <li>S. Ensure consistency between Cultural Heritage Management Plan and Closure Management Plan with respect to strategies for maintaining cultural heritage values.</li> </ol>

### **APPENDIX E - LANDFORM DESIGN CRITERIA**

### Deposit A South Dump

Erodibility Ranking	Moderate to High
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🗆
Footprint (ha)	318
Overall height (RL/m)	105

	Construction	Rehabilitation
	Specifications	Specifications
Slope angle (degrees)	37	17 (under review)
Lift Height (m)	Range 10-20	12-15 (under review)
Berm width (m)	Range 34-68	10
Berm slope (degrees)	0	-10

#### Comments

A section of the waste dump was rehabilitated in 2012.

Rehabilitation designs have been developed for the dump, but will require substantive modification to address the following issues:

- 1. The dump is situated within the assumed zone of instability around the Deposit A pit, and a proposed cutback within the pit would magnify this issue. Material will need to be removed from the northern side of the dump to ensure that the final rehabilitation slope is outside of this zone.
- 2. The dump was originally constructed to achieve rehabilitation slopes with lift heights of up to 20m, as was typical at the time. Subsequent material characterisation has highlighted a predominance of erodible detrital and shale material, which would require much smaller lift heights. Based on evaluation of the 2012 rehabilitated slope, the rehabilitation specifications presented in the table above would be sufficiently stable, but further testing is required to confirm this.
- 3. The dump has been over-tipped beyond the target construction specifications.

The rehabilitation strategy and designs presented in the previous version of the closure plan are now considered obsolete for the reasons stated above, and are currently being reevaluated. Revised designs will be presented in the next closure plan update.

#### Construction Design



### **Rehabilitation Design**

To be presented in the next closure plan update

### Deposit A North Dump (incorporating previous 'East Dump')

Erodibility Ranking	Moderate to High
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🖂
Footprint (ha)	237
Overall height (RL/m)	90

	Construction	Rehabilitation
	Specifications	Specifications
Slope angle (degrees)	37	17 (under review)
Lift Height (m)	20	12-15 (under review)
Berm width (m)	68	10
Berm slope (degrees)	0	-10

#### Comments

A section of the waste dump was rehabilitated in 2012.

Rehabilitation designs have been developed for the dump, but will require substantive modification to address the following issues:

- The dump was originally constructed to achieve rehabilitation slopes with lift heights of up to 20m, as was typical at the time. Subsequent material characterisation has highlighted a predominance of erodible detrital and shale material, which would require much smaller lift heights. Based on evaluation of the 2012 rehabilitated slope, the rehabilitation specifications presented in the table above would be sufficiently stable, but further testing is required to confirm this.
- 2. The dump has been over-tipped beyond the target construction specifications.
- 3. A cell of fibrous minerals is present relatively close to the surface, and rehabilitation designs will need to ensure that it remains sufficiently encapsulated with inert material.

The rehabilitation strategy and designs presented in the previous version of the closure plan are now considered obsolete for the reasons stated above, and are currently being reevaluated. Revised designs will be presented in the next closure plan update.

### **Construction Design**



### **Rehabilitation Design**

To be presented in the next closure plan update

### Deposit A West Pit North backfill

Erodibility Ranking	Moderate to High
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🗆
Footprint (ha)	146
Overall height (RL/m)	40

	Construction	Rehabilitation
	Specifications	Specifications
Slope angle (degrees)	37	17 (under review)
Lift Height (m)	20	12-15 (under review)
Berm width (m)	45-68	10
Berm slope (degrees)	0	-10

#### Comments

This waste dump is a section of the Deposit A pit which has been backfilled to above the natural topography level.

Rehabilitation designs have been developed for the dump, but will require substantive modification to address the following issues:

1. Additional waste will be required to be placed into Deposit A pit to prevent the formation of a permanent pit lake. The strategy for achieving this is currently being developed, and will influence the rehabilitation design of this dump.

The rehabilitation strategy and designs presented in the previous version of the closure plan are now considered obsolete for the reasons stated above, and are currently being reevaluated. Revised designs will be presented in the next closure plan update.

### **Construction Design**



### **Rehabilitation Design**

To be presented in the next closure plan update

### Deposit B East Dump

Erodibility Ranking	Moderate to High
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🛛
Footprint (ha)	209
Overall height (RL/m)	75

	Construction	Rehabilitation
	Specifications	Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	34-68	10
Berm slope (degrees)	0	-10

### Comments

There is a lower proportion of erodible wastes present at Deposit B than in other West Angelas deposits, and selective dumping is proposed to ensure that competent materials (e.g. BIF) are located on the outer surface of the dump.

The dump will contain material that is classified as potentially fibrous –this material will be encapsulated with inert material if fibres are encountered.

### **Construction Design**





### Deposit B West Dump

Erodibility Ranking	Moderate to High
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🗆
Footprint (ha)	209
Overall height (RL/m)	75

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	34-68	10
Berm slope (degrees)	0	-10

### Comments

There is a lower proportion of erodible wastes present at Deposit B than in other West Angelas deposits, and selective dumping is proposed to ensure that competent materials (e.g. BIF) are located on the outer surface of the dump.

### **Construction Design**





## Deposit B Low Grade Dump

Erodibility Ranking	Low
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🗆
Footprint (ha)	75
Overall height (RL/m)	80

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	34-68	10
Berm slope (degrees)	0	-10

Comments

### **Construction Design**





### Deposit C and D waste dumps (conceptual)

Erodibility Ranking	Moderate to High
Classification	Inert 🛛 PAF 🗌 Fibrous minerals 🗌
Footprint (ha)	-
Overall height (RL/m)	-

	Construction	Rehabilitation
	Specifications	Specifications
Slope angle (degrees)	37	17 (under review)
Lift Height (m)	20	12-15 (under review)
Berm width (m)	34-68	10
Berm slope (degrees)	0	-10

#### Comments

Deposit C and D mineral wastes are expected to perform similarly to those at Deposit A, and similar rehabilitation strategies are expected. Further testing will be required to confirm material characteristics.

Waste dump designs are still at a conceptual stage. Original designs have recently been modified to avoid disturbance of a significant heritage site, and further design adjustments may be required as new knowledge arises. Rehabilitation designs will be developed following confirmation of the construction design.

In addition to external waste dumps, waste will be deposited directly into pit voids when areas become available. Rehabilitation of these areas may be required if backfill extends to (or near to) the ground surface.

### **Conceptual Construction Design**





### Deposit E South waste dump

Erodibility Ranking	Moderate to High (Low when capped)
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🗆
Footprint (ha)	125
Overall height (RL/m)	80

	Construction	Rehabilitation
	Specifications	Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	43	15
Berm slope (degrees)	0	-10

### Comments

Material emanating from Deposit E is of generally of moderate to high erodibility. However, there is a significant proportion of hydrated material which is sufficiently competent to be used as a capping layer to protect the surface of the dump from erosion. Stockpiles of the material will be used to cap the dump prior to rehabilitation, and this will allow less conservative design specifications to be applied than elsewhere at the site.

### **Construction Design**





### Deposit E West waste dump

Erodibility Ranking	Moderate to High (Low when capped)
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🗆
Footprint (ha)	35
Overall height (RL/m)	43

	Construction	Rehabilitation
	Specifications	Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	43	15
Berm slope (degrees)	0	-10

### Comments

Material emanating from Deposit E is generally of moderate to high erodibility. However, there is a significant proportion of hydrated material which is sufficiently competent to be used as a capping layer to protect the surface of the dump from erosion. Stockpiles of the material will be used to cap the dump prior to rehabilitation, and this will allow less conservative design specifications to be applied than elsewhere at the site.

### **Construction Design**





### Deposit F waste dumps (West Dump, East Dump, Low Grade Dump)

Erodibility Ranking	Moderate to High (Low when capped)
Classification	Inert 🛛 PAF 🗆 Fibrous minerals 🗆
Footprint (ha)	35
Overall height (RL/m)	43

	Construction	Rehabilitation
	Specifications	Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	43	15
Berm slope (degrees)	0	-10

### Comments

Material emanating from Deposit F is generally of moderate to high erodibility. However, there is a significant proportion of hydrated material which is sufficiently competent to be used as a capping layer to protect the surface of the dump from erosion. Stockpiles of the material will be used to cap the dump prior to rehabilitation, and this will allow less conservative design specifications to be applied than elsewhere at the site.

### **Construction Design**



